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A Remarkable Textbook

Barber's First Course in General Science

By Frederick D. Barber, Professor of Physics in the Illinois State Normal University, Merton L. Fuller, Lecturer on Meteorology in the Bradley Polytechnic Institute, John L. Pricer, Professor of Biology in the Illinois State Normal University, and Howard W. Adams, Professor of Chemistry in the same. vii + 588 pp. of text. 12mo. $1.25.

A recent notable endorsement of this book occurred in Minneapolis. A Committee on General Science, representing each High School in the city, was asked to outline a course in Science for first year High School. After making the outline they considered the textbook situation. In this regard, the Committee reports as follows:

"We feel that, in Science, a book for first year High School use should be simple in language, should begin without presupposing too much knowledge on the part of the student, should have an abundance of good pictures and plenty of material to choose from.

Barber's *First Course in General Science* seems to us to best meet these requirements and in addition it suggests materials for home experiments requiring no unusual apparatus, and requires no scientific measurements during the course. We recommend its adoption."

Other Interesting Opinions on the Book Follow:

School Science and Mathematics:—It is one of the very best books on general science that have ever been published. The biological as well as the physical side of the subject is treated with great fairness. There is more material in the text than can be well used in one year's work on the subject. This is, however, a good fault, as it gives the instructor a wide range of subjects. The book is written in a style which will at once command not only the attention of the teacher, but that of the pupil as well. It is interesting from cover to cover. Many new and ingenious features are presented. The drawings and halftones have been selected for the purpose of illustrating points in the text, as well as for the purpose of attracting the pupil and holding his attention. There are 375 of these illustrations. There is no end to the good things which might be said concerning this volume, and the advice of the writer to any school board about to adopt a text in general science is to become thoroughly familiar with this book before making a final decision.

Walter Barr, *Keokuk, Iowa*:—Today when I showed Barber's Science to the manager and department heads of the Mississippi River Power Co., including probably the best engineers of America possible to assemble accidentally as a group, the exclamation around the table was: "If we only could have had a book like this when we were in school." Something similar in my own mind caused me to determine to give the book to my own son altho he is in only the eighth grade.

G. M. Wilson, *Iowa State College*:—I have not been particularly favorable to the general science idea, but I am satisfied now that this was due to the kind of texts which came to my attention and the way it happened to be handled in places where I had knowledge of its teaching. I am satisfied that Professor Barber, in this volume, has the work started on the right idea. It is meant to be useful, practical material closely connected with explanation of every day affairs. It seems to me an unusual contribution along this line. It will mean, of course, that others will follow, and that we may hope to have general science work put on such a practical basis that it will win a permanent place in the schools.

Henry Holt and Company

NEW YORK **BOSTON** **CHICAGO**

THE SCIENTIFIC MONTHLY

DECEMBER, 1917

A PHOTOGRAPHIC RESEARCH LABORATORY[1]

By DR. C. E. KENNETH MEES

RESEARCH LABORATORY, EASTMAN KODAK CO., ROCHESTER, PA.

THE research laboratory of the Eastman Kodak Company was established in 1912 to study the problems involved in the production and use of photographic materials.

Photographic research occupies a somewhat unique position in the field of applied science both because photography is so much used in other scientific work that interest in it is very widespread and because the methods of photographic research are so different from those of all other branches of scientific work that it is rare for the professional scientific man to understand them.

Very little work on the theory of photography has been done in the universities and there are perhaps three reasons for this: In the first place, information with regard to the theory of photography is not easy to obtain; there are few books on the subject and these deal generally with only a limited part of the field, and the original papers to which recourse must be had for information are scattered through a wide range of photographic and other journals. In the second place, work on the theory of photography necessarily involves work with photographic materials, and these materials are now made entirely by manufacturing companies, the methods of manufacture not being disclosed, so that the actual nature of the photographic materials themselves is but little understood by the user of them. In the third place, the apparatus required for photographic research is very specialized and somewhat expensive.

Our knowledge of photographic theory we owe chiefly to enthusiastic amateur photographers, supplemented in recent

[1] Being a paper read before the American Physical Society at the Rochester meeting.

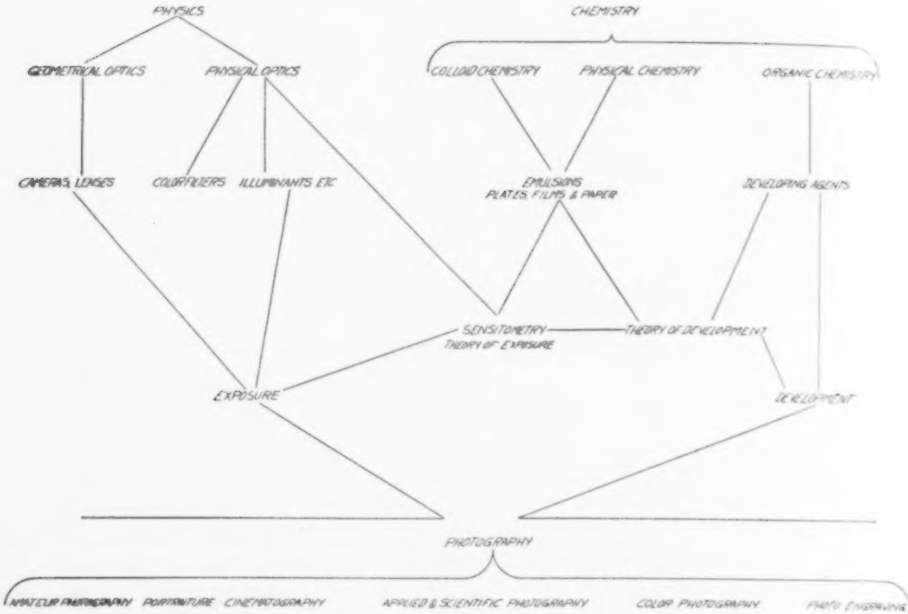

FIG. 1.

years by the research done by the photographic manufacturing firms, and it was in order to produce a considerable increase in the amount of this specialized photographic research work that the Eastman Kodak Company established its research laboratory.

The work of the laboratory deals, of course, not only with the theory of photography but with many points of practical importance both in the manufacture of photographic materials and apparatus and in their use, and the laboratory is divided into different sections corresponding to the general divisions of science, notably physics, chemistry and practical photography, the workers in these divisions collaborating in investigation of the problems with which the laboratory is concerned.

The branches of science which are of chief importance in photographic problems are those of optics in physics and of the colloid, physical and organic divisions of chemistry, and Fig. 1 represents an attempt to show the relations of these branches of science to photography.

Optics deals on its geometrical side with the materials used in photography—cameras, lenses, shutters, etc.—and on its physical side with such materials as color filters and illuminants, but especially with the study of the relation of the photographic image to the light by means of which it was produced —a study which is known by the name of sensitometry.

The manufacture of the sensitive material itself, which in the case of modern photographic plates, films and paper is called the "emulsion," is a province of colloid and of physical chemistry, colloid chemistry dealing with the precipitation and nature of the sensitive silver salts formed in their gelatine layer, while physical chemistry informs us as to the nature of the reactions which go on, both in the formation of the sensitive substance and in its subsequent development after exposure.

The organic chemist prepares the reducing agents required for development and the dyes by which color sensitiveness is given to the photographic materials and by which the art of color photography can be carried on, and while the physicist therefore deals with sensitometry and the theory of exposure, the chemist must deal at the same time with the theory of development and with the conditions relating to the development of photographic images.

A laboratory, therefore, for the study of photographic problems must be arranged with a number of sections such as are shown in Fig. 2. There will be physical departments, dealing

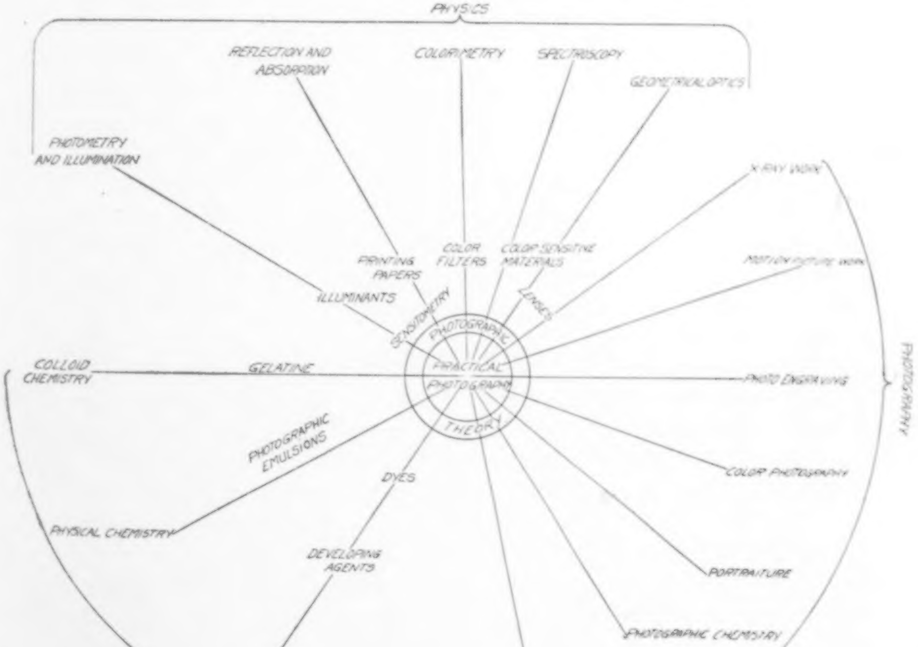

Fig. 2.

with sensitometry and illumination, reflection and absorption, colorimetry, spectroscopy and geometrical optics. There will be a department of colloid chemistry, one of physical chemistry, one of organic chemistry, one of photo-chemistry to deal with the action of light upon a plate, and finally a number of photographic departments, dealing with photographic chemistry, with portraiture, color photography, photo-engraving, motion picture work and X-ray work, and the results obtained in all these departments will be applied first to the theory and then to the practise of photography.

In order to concentrate the different departments of the laboratory upon the photographic problems that arise and to ensure that on each problem the full knowledge and experience of the different specialists is made available, the main lines of work under investigation are discussed at a morning conference at the beginning of the day's work, one day of the week being assigned to each special subject, so that on Monday, for instance, those doing work in relation to one subject meet; on Tuesday the same men or other workers discuss a second aspect of the work of the laboratory, and so on. The laboratory organization, then, resolves itself into these several groups,

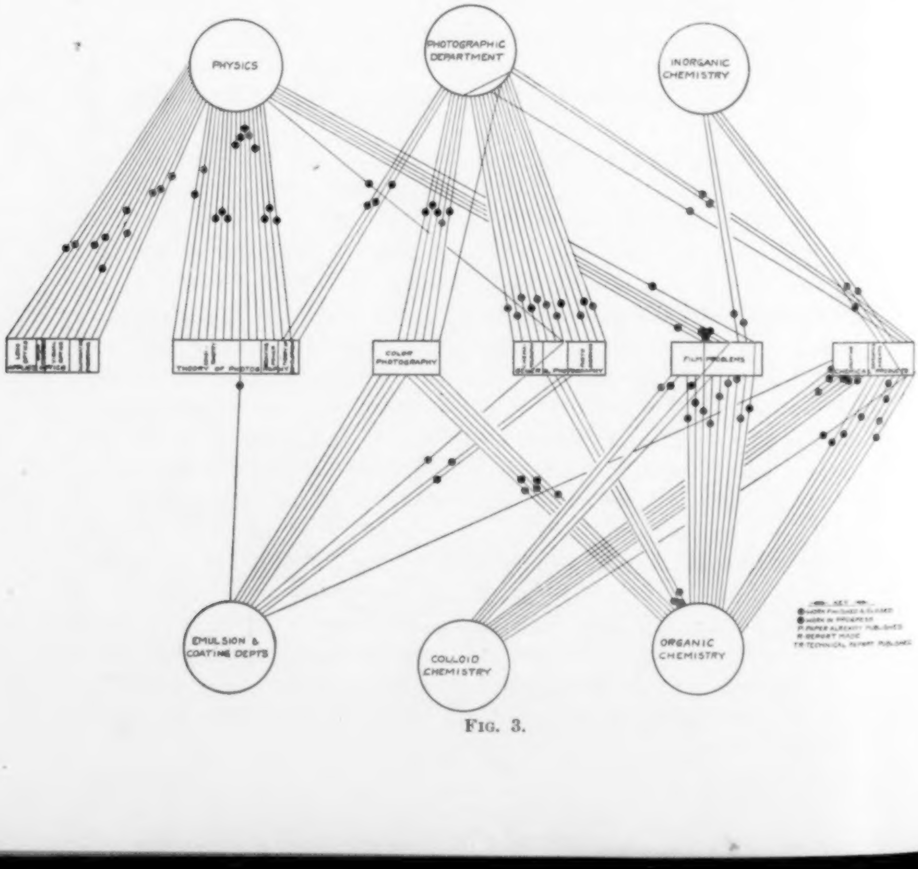

FIG. 3.

interlocked by their common members, who are dealing with a number of different lines of work.

The total work of the laboratory during the year may be represented by Fig. 3.

The departments of the laboratory are represented as circles on the outside of the chart, the main divisions in which problems group themselves being represented by the rectangles, subdivided in some instances, occupying the middle of the chart. Each of these rectangles corresponds to a morning conference; thus on Thursday mornings a conference is held on general photography, at which there are present members of the photographic department, the physics department, and the emulsion and coating or manufacturing departments. There is present at the conference, in fact, every scientific worker of the laboratory, whatever his rank, who is directly engaged on the subjects which are included under the head of general photography, and in some cases, or on special occasions, members of the staff of the company external to the laboratory are invited to these conferences, although it is not possible for many of them to be regularly present. All the main lines of investigation are laid down at these conferences and the progress from week to week carefully discussed. By the use of this system full cooperation and concentration of the different sections of the laboratory upon the problems to study which it has been founded is ensured.

Since the establishment of the laboratory, which was completed in 1913, a good deal of work has been finished and the foundations laid for much further research which can now be considered to be planned and arranged.

The work of the laboratory is published in the form of scientific papers, these being printed in the usual technical journals to which the special subject of the paper may be appropriate, and then at intervals, as sufficient papers accumulate, full abstracts of all the papers are collected and published in a volume under the title of "Abridged Scientific Publications." At the time of writing, October, 1917, about 65 papers have been completed.

The scientific work of the laboratory can be classified under the headings of the physics of photography, the chemistry of photography, the reproduction of tone values by photography, and work on special photographic processes, including those required for photography in natural colors. In addition to this a considerable amount of research has been done in pure chemistry and in the various branches of applied optics which are closely allied to photography.

THE PHYSICS OF PHOTOGRAPHY

Photographic sensitive surfaces do not consist of continuous coherent films of homogeneous material but have a definite granular structure, the sensitive material itself consisting of grains embedded in an insensitive matrix, so that in considering the properties of a sensitive photographic material we are considering really the properties of a collection of sensitive grains, which may differ considerably from each other in their individual properties. The properties of such a collection will be the statistical average of the individuals composing it and in order to understand the properties of a sensitive material we must therefore consider the properties of the individual grains and their relation to the aggregate material of which they are units.

The question at once arises: Do these grains consist of crystals of pure silver halide or of a gelatine silver complex? Microscopical study shows it to be probable that the grain is a pure silver halide crystal, for when these crystals are exposed to the action of water no swelling at all is observable even under the highest power of the microscope. The grains of silver bromide prove to be regular semi-transparent crystals belonging to the isometric system, occurring chiefly in triangular and hexagonal tablets and in needles of various thick-

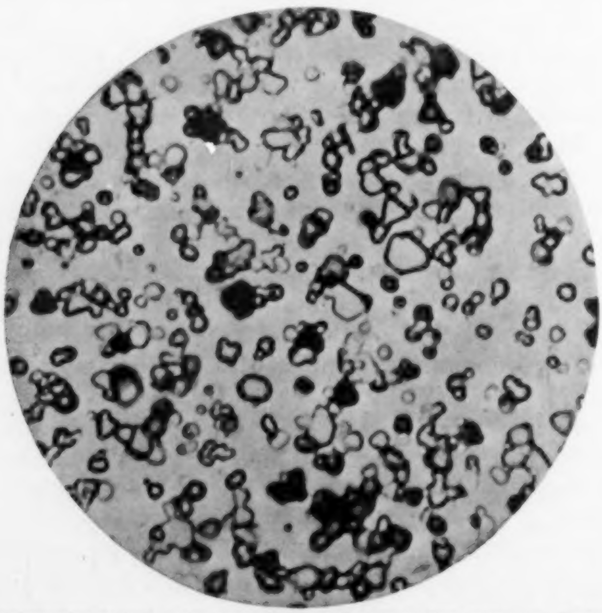

FIG. 4. PHOTOMICROGRAPH SHOWING SILVER BROMIDE CRYSTALS IN PHOTOGRAPHIC EMULSION.

nesses, these needles being formed in the same way as the tablets (see Fig. 4). As they occur in a gelatine emulsion, these grains are doubly refracting, though this would not have been expected from their crystalline form (see Fig. 5). Silver

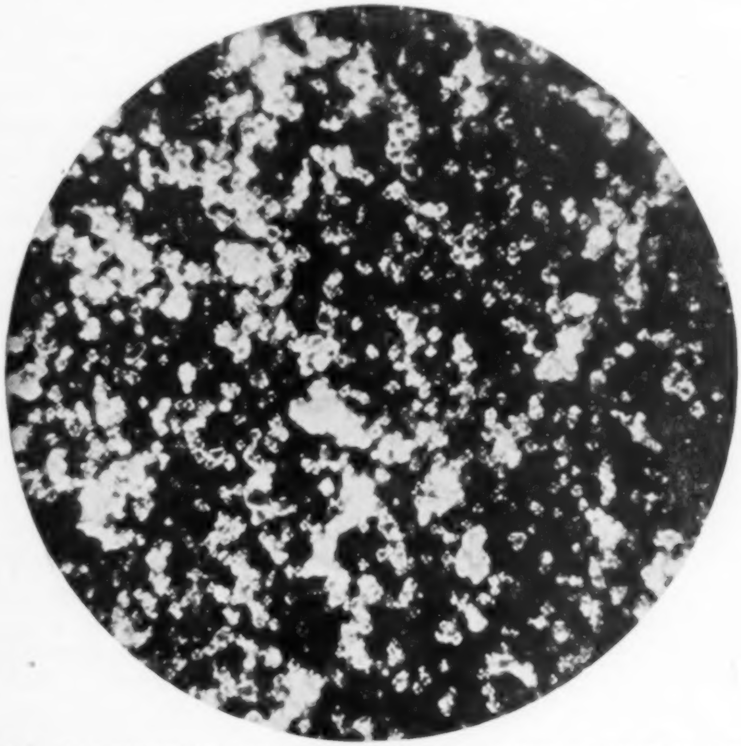

FIG. 5. PHOTOMICROGRAPH OF CRYSTALS OF SILVER BROMIDE BY POLARIZED LIGHT SHOWING DOUBLE REFRACTION

bromide can be crystallized out from its solution in ammonia to show all the forms in which it occurs in emulsions, and the physical chemistry of the preparation of these crystalline grains is under investigation in the laboratory at the present time.

When the silver halide grains are developed, the crystalline form is lost, the silver being deposited in a sponge-form in soot-like particles, the form of the deposit being generally considerably distorted from the original shape of the silver bromide crystal grain, though in some cases the original shape is fairly well reproduced in the deposit of metallic silver.

In viewing a negative by transmitted light we can not, of course, see these isolated grains with the naked eye but we see a conglomeration caused by the penetration of light through the interstices between the grains distributed throughout the

emulsion layer, and thus we obtain regular large patches or chains of grain, the pattern and regularity depending upon the particular type of emulsion used. This granularity, the formation of which can be studied by the examination of a vertical section through the film, is what is meant by the "graininess" of photographic negatives in general and is the grain met with in enlarging, in projection, and in portraiture.

The granular structure of a photographic emulsion involves a limit to the resolving power of the emulsion; that is, it requires a certain finite distance between two points of light falling upon the film in order that they may record themselves as separate deposits of silver grains. The study of the resolving power of a photographic emulsion can be accomplished by the examination of the spread of the edge of an image. Suppose, for instance, that we lay upon a photographic film a knife edge and then illuminate this knife edge vertically from above; some of the light passing the knife edge will be scattered into the shadow by reflection from the grains of silver bromide and will produce developable grains within the shadow so that upon development we shall obtain a distinct extension of the image beyond the edge into the shadow. If we determine the relation between the number of grains rendered developable and the distance from the edge, we shall have a relation which will depend upon the scattering of the light by the silver bromide grains and upon the absorption of that light by the grains. These two factors we might term the "turbidity" and "opacity" of the emulsion.

An emulsion having high turbidity and low opacity will have a very low resolving power. On the other hand, even if the emulsion has high turbidity, if its opacity is also high, the resolving power may be good. A typical example of this is the wet collodion plate, in which the turbidity is considerable but the opacity of the silver iodide for blue-violet light is so great that the resolving power is high. In the grainless Lippmann emulsion the resolving power is high if the emulsion is very clear, because the turbidity is very small, but the opacity is also small so that the slightest increase in turbidity may make the resolving power very low.

A convenient way of measuring resolving power is to photograph a converging grating, observing the point in the photograph at which resolution first occurs, from which a numerical measurement of the resolving power can be obtained.

The importance of photographic resolving power in relation to many branches of scientific work and especially spectro-

scopy and astronomy is obvious, and much work is being done in the laboratory upon these applications.

Of course, the fundamental problem in the physics of photography is the effect of the light on the film itself; that is to say, the change which occurs in a grain of silver bromide when it is exposed to light that makes it developable. It is extremely difficult to attack this directly, and the only possibility of evidence which we have been able to get is a statistical calculation by Dr. Nutting as to the amount of light which will produce a developable grain of silver bromide. Consider the exposure to light which is sufficient after full development to produce a deposit of unit density, that is, one which will transmit one tenth of the incident light.

A deposit which has this density contains 10 milligrams of metallic silver per square decimeter, or one tenth milligram per square centimeter, which represents roughly 10^{19} molecules of silver, or 10^{7} grains $3\,\mu$ in diameter. Now, the energy of the amount of violet light required to give an exposure necessary to make en emulsion film developable to this density is of the order of 10^{-7} ergs per square centimeter. Therefore, each grain (which contains on the average 10^{12} molecules) receives 10^{-14} ergs to make it developable. We know that in order to detach one electron from a molecule, 5×10^{-12} ergs are required in a gas; but this is a maximum amount and it is possible that in the exposure of a photographic plate 10^{-14} ergs are sufficient to detach one electron. Clearly, then, the energy incident on a grain during exposure may be sufficient to affect only one molecule in that grain, and the latent image may be composed of grains in each of which, on the average, only one molecule has lost an electron by the action of light.

The Chemistry of Photography

While the grain structure of the emulsion and its reaction to light must be considered a branch of physics, the development of the emulsion is certainly closely related to physical chemistry. One of the most interesting pieces of work in the laboratory has been the study of the photographic developers in relation to their behavior in the development of the latent image, and the relation of the constitution of the many compounds possible to their properties is being attacked in the laboratory by the collaboration of the department of organic chemistry, which prepares the compounds in question, and of a special laboratory which deals with the physical chemistry of developers. In this laboratory the developers are examined

both by their action upon the photographic emulsion and also by the recognized methods of physical chemistry. The most fundamental property of a developing agent is its reduction potential, and this should apparently be measurable electrically by comparing the electromotive force produced on a platinized cathode immersed in the developing agent with the potential of an electrode charged with gaseous hydrogen.

The rate of development is dependent on two factors: first, on the rate of the chemical reaction itself; that is, on the solution of silver bromide, its conversion into metallic silver, and the precipitation of the metallic silver in a solid form; and, secondly, on the rate of diffusion of the developer to the silver bromide grain and of the products of development away from the grain. The second of these factors has by far the greater influence in settling the rate of development, though the time of first appearance of the image appears to be dependent chiefly upon the rate at which the developer attacks the silver bromide grain. It is in the rate of attack on the silver bromide grain that the reduction potential plays so great a part, but this rate of attack under ordinary conditions is limited by the rate of solution of the silver bromide, and a developer does not attack the silver bromide grain proportionally faster by reason of an increased reduction potential.

The reduction potential of a developer, in fact, may be compared to the horse power of an automobile, which for other reasons than the power of its engine is limited in speed. If we have two automobiles and they are confined to a maximum speed of twenty miles an hour, then on flat roads the one with the more powerful engine may be no faster than the weaker, but in a high wind or on a more hilly road the more powerful engine will allow the automobile to keep its speed, while with a weaker engine the speed would fall off; we can, indeed, measure the horse power of an automobile by the maximum grade which it can climb at a uniform speed. In development the analogy to the hill is the addition of bromide to the developer, since the addition of bromide, by the lowering of the solubility of the silver bromide, greatly delays the chemical reaction in development, and the higher the reduction potential of a developer, the more bromide is required to produce a given lowering of the density, so that we can measure the reduction potential by the amount of bromide required to produce a given effect. If we measure the common developers in this way, we shall find that glycin has the lowest reduction potential, then hydrochinon, then pyro and paraminophenol, and finally elon and diamidophenol have the highest.

The Reproduction of Tone Values

The aim of photography is to reproduce in the print the scale of light intensities which occurs in the original subject, and the study of the way in which a scale of brightnesses is reproduced in the photographic process from the original subject through the negative to the print is necessarily the main study of a photographic research laboratory.

There are four separate sections involved in this investigation: first, the study of the range of brightnesses occurring in natural objects such as one is required to photograph; second, the study of the way in which the photographic emulsion translates a scale of light intensities into deposits of metallic silver in the negative; third, the study of the properties of photographic printing papers and the relation of the reflecting power of the deposits obtained in them to the scale of light intensities to which they were exposed; and, fourth, the study of the accuracy with which the tone values of the original are rendered through the negative on to the printing paper.

Until recently the scale of rendering of the negative material itself was all that had been fully investigated. This was done by Hurter and Driffield in their famous photo-chemical investigation published in 1890, in which they measured the relation between the exposure of the sensitive material to light and the optical density produced. This density they defined as being the logarithm of the reciprocal of the transparency, and

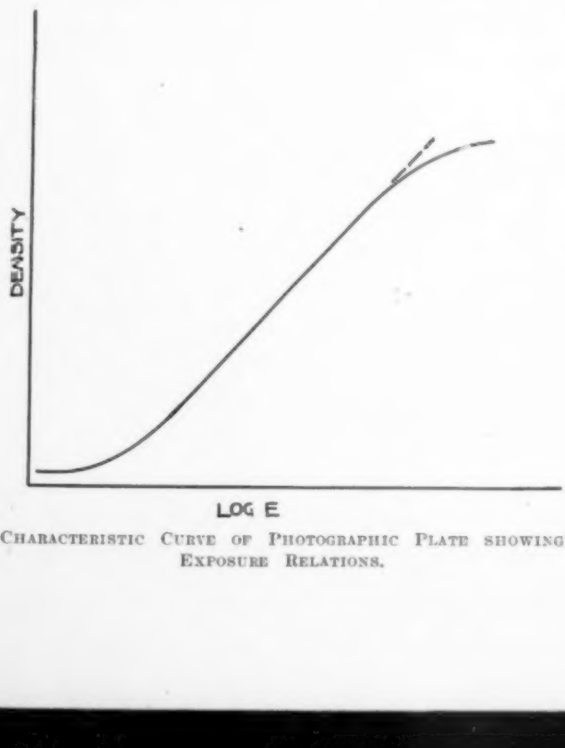

Fig. 6. Characteristic Curve of Photographic Plate showing Density Exposure Relations.

they found that it was proportional to the mass of silver per unit area. In their curves they plotted the density against the logarithm of the exposure, thus obtaining a curve which for the greater portion of its length is a straight line, though at the beginning and the end it departs from the straight line law (Fig. 6). It is only where the curve is a straight line that correct translation of the light intensities of the original into the density of the negative occurs. The study of these relations is what is known as "sensitometry" and forms a large part of photographic investigation in itself.

Much work has been done in the laboratory on the effect of development on the rendering of tone values in the negative and especially of development in those solutions which produce a somewhat colored image. If a negative be developed with pyrogallic acid the image produced is of a yellowish color, and it has a very different contrast when printed on the usual violet-sensitive photographic materials to that which is obtained when it is measured optically by means of the eye. The study of the relation of the photographic to the visual density of such images has in itself involved a very considerable amount of investigation.

In order to render possible the study of the reproduction occurring in photography an investigation of the sensitometry of papers was necessary.

In the first place, an instrument was designed by means of which the light reflected from small areas of the exposed print could be measured. Papers were then exposed for known periods of time, developed, the reflecting power of the developed image measured and curves plotted of the logarithm of the reciprocal of the reflecting power against the logarithm of the exposure. Several constants were found to express the behavior of photographic papers; thus, any paper had a maximum density, that is a minimum reflecting power representing the deepest black which could be obtained upon it. It showed also a typical scale or total range of exposures through which any difference could be obtained with an alteration of exposure. Again, the straight line portion of the curve showed a definite steepness or "gamma," as we call it, and finally the length of the straight line portion is of great importance, since it is only throughout this straight line portion that exact reproduction can be obtained (Fig. 7).

As a result of the work which has been done we are now able to give a complete solution for the translation of the scale of tone values of an original subject through the negative on to

the printing paper, showing how far the light reflected from the deposits in the print will correspond to the brightness existing in the original subject, and finding the effect of alterations in either the negative-making material or in the printing medium on the accuracy of the reproduction, as well as the effect of differences of development and exposure. A series of papers dealing with the whole subject of tone reproduction is in preparation at the present time.

Other branches of sensitometry are under investigation in the laboratory: thus, we have made a very careful study of the effect upon the sensitiveness of the photographic material of the variation of the wave length of the light to which it is ex-

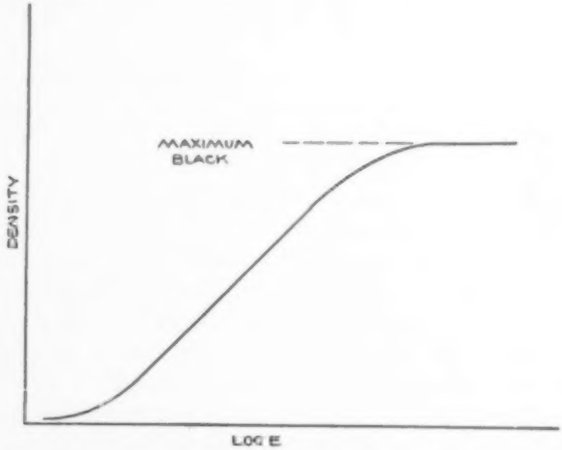

FIG. 7. CHARACTERISTIC CURVE OF PHOTOGRAPHIC PAPER SHOWING DENSITY-EXPOSURE RELATIONS.

posed, and for this purpose have constructed a special wavelength sensitometer with which a number of different materials have been investigated throughout their entire range of sensitiveness.

The study of the sensitiveness of photographic materials towards the X-rays is of considerable importance and for this purpose we have built special sensitometers for radiographic work. In the older types of sensitometers the exposure was graduated by means of a rotating disk from which sectors of varying angle were cut out, but it is known that the intermittent exposures given by such an arrangement do not integrate correctly, the density produced by a number of small exposures being less than that produced by the corresponding exposures impressed continuously. In X-ray work, moreover, there is a danger of stroboscopic effects produced by the rotating sector

getting in phase with the X-ray generator, which delivers a pulsating current, and there has therefore been designed in the laboratory a new type of non-intermittent sensitometer in which the exposures are given automatically and continuously, and this has proved very useful for many kinds of work and especially for radiographic sensitometry.

Practical Photography

Naturally, a great portion of the work of the laboratory is concerned with photographic processes and work on all kinds of photographic processes is continually in progress. It is difficult to summarize this work in any brief form, but the work which is being done on color photography is perhaps especially worthy of note.

There are two main divisions of the practical processes of color photography: the processes which are known as "additive," in which the colors are produced by the superposition upon a projection screen or in the eye of beams of the primary colors, and the "subtractive" processes in which negatives taken through the primary filters are printed in colors complementary to those filters and these prints are then superposed.

Most of the work of the laboratory has dealt with the subtractive processes, though a good deal of research work has been done upon the filters required for the additive processes and upon such subjects as the color of mixtures of two nearly complementary colors, work which is of considerable interest in connection with the two color additive processes.

In work on the subtractive process of color photography some interesting results have been achieved in the photomicrography of stained sections, a two-color process having been developed which gives very good results for this purpose. The two-color subtractive process of color photography has also been applied to motion picture work, the pictures being made by using film coated on both sides with a sensitive emulsion, so that negatives taken through the red and green filters can be impressed in register on opposite sides of this double-coated film and then the double images after development can be transformed into dye images complementary in color to the filters through which the negatives were taken. In this way each picture on the film consists of two pictures of complementary colors which give the effect of a two-color subtractive picture. This process, of course, has the great advantage that film so made is suitable for projection in any ordinary motion-picture machine.

Applied Optics

Owing to the great importance of applied optics in all photographic work the physics department of the laboratory has done a good deal of research in relation to this subject.

One branch of applied optics which has not previously received the attention which it seems to deserve is the study of the sensitiveness of the eye to light, and since the sensitometry of the eye is comparable in many respects to that of photographic materials a special series of investigations have been made on this subject in the laboratory as a result of which we have obtained new data with regard to the change of sensitiveness of the eye with different levels of brightness and to the rate of adaptation of the eye when the illumination is changed. A very recent piece of work deals with the change in size of the pupil with the brightness.

In pure applied optics a number of studies have dealt with the reflection and transmission of light by diffusing media and with photometry and brightness measurements, the laboratory being especially well equipped to study absorption photometry both with and without a consideration of color. The study of color in all its branches has occupied a large part of the activities of the physics department. Thus, measurements have been made on the sensibility of the eye to color and to change of hue, and a number of investigations have been made on the use of the monochromatic colorimeter in the quantitative expression of color.

Light filters are of great importance in photography, and the manufacture of light filters for all purposes was commenced with the establishment of the laboratory and has been continued as one of the manufacturing activities of the laboratory since. Over one hundred differently colored light filters are made, including filters applicable to all branches of scientific work. Special filters are made for microscopy, spectroscopy, photometry, etc. The measurement on the spectro-photometer of the absorption curves, both of these filters, and of the organic dyestuffs from which they are prepared, has been a subject of a considerable amount of study, and many interesting results have been obtained both in the visible spectrum and in the ultra-violet.

The work done in the laboratory up to the present time is really, of course, initial work, since the laboratory has only been in active operation for four years, but it is possible already to see the tendency of the work of the laboratory to converge more and more closely upon the purely photographic problems

which present an ample field for the entire energy of the laboratory and it is probable that the output of work on photographic questions will steadily increase as more experience is accumulated in the handling of the problems involved.

In addition to the scientific work of the laboratory on the theory of photography, which is referred to in this paper, a great number of industrial questions and works' problems are, of course, referred to the research laboratory, and it has been found that an organization arranged for the study of the fundamental problems of the theory of photography is well suited to taking care of these works problems and practical questions as they arise, each problem being assigned to the specialist who appears best fitted to deal with it, and it is understood by all the men in the laboratory that a certain part of their time will necessarily be devoted to the study of problems originating in the commercial and manufacturing departments of the company.

THE WORK OF THE NORTH DAKOTA BIOLOGICAL STATION AT DEVIL'S LAKE

By Professor R. T. YOUNG

UNIVERSITY OF NORTH DAKOTA

DEVIL'S Lake, the euphonious substitution for the Indian Minnewaukon, or Spirit Water, is the name of one of the countless glacial lakes of northern North America. It is located in latitude 48, longitude 99, in North Dakota, at an altitude of 1,424 ft., in the upland prairie, which rises gradually from the Red River Valley to the high tableland, which sweeps westward through Montana to the Rocky Mountains.

It was formed by a morainic dam built by the ice across an old river valley, and originally drained southward through Stump Lake into the Sheyenne River (Fig. 1). At one time during the retreat of the continental ice sheet the glacial lake

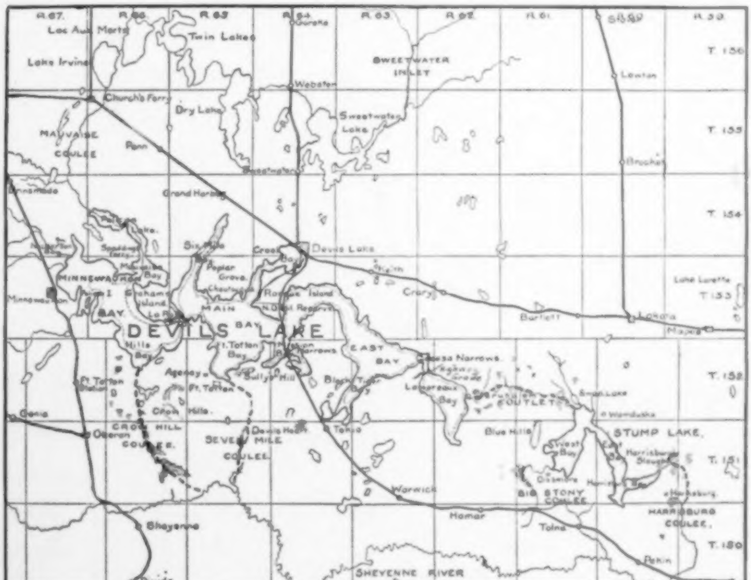

FIG. 1. MAP OF THE DEVIL'S-STUMP LAKE COMPLEX, showing the former connection of Devil's Lake with the Sheyenne River, via the Jerusalem outlet, Stump Lake and the Harrisburg Coulée. The full shore line is from the U. S. G. S. map of 1883. The dotted line shows the present shore line approximately. (From Simpson in N. D. G. S. Report for 1909-10.)

Souris, occupying a part of northern North Dakota and southern Manitoba west of the glacial lake Agassiz, found an outlet via the Mauvaise Coulée and the Devil's-Stump Lake basin into the Sheyenne River. With the disappearance of this lake the drainage area was restricted to about 3,500 square miles between Devil's Lake and the Turtle Mountains, a group of low morainic hills on the Canadian boundary.

With the retreat of the ice and consequent diminution of moisture, the evaporation of Devil's Lake came in time to exceed its supply, the connection with Stump Lake and the Sheyenne River was lost and its subsequent history has been in general one of gradual recession. Between 1885 and 1890, the connection with the Mauvaise Coulée was lost except during spring freshets, but the very heavy snowfall of 1916 has restored this.[1]

There is considerable reason to believe that the recession of the lake has not been constant, but that at least one period has intervened when it was much lower than at present, if not entirely absent. The evidence for this is the existence of an old forest in Stump Lake, from which the lake derives its name (Figs. 2 and 3); the presence of a submerged terrace (indicative of a former shore line) in Devil's Lake, similar to those

FIG. 2. STUMP LAKE, showing remains of submerged forest, from which the lake derives its name. (Simpson, photo.)

[1] This coulée is again dry—1917.

FIG. 3. ONE OF THE STUMPS OF THE SUBMERGED FOREST IN STUMP LAKE. (Simpson, photo.)

about its shores; and the existence of rock piles in the lake which were probably formed by ice action during periods of lower level (Fig. 4). With continued recession of the lake, many small ponds have been separated from the main body, and this process is still continuing. Three highway embank-

FIG. 4. ROCK PILE IN DEVIL'S LAKE. These glacial boulders have been piled up through ice action, and are evidence of a former lake level as low or lower than the present. (Simpson, photo.)

ments have recently been built across the lake, which together with its recession have divided it into four main parts. Taken as a whole the form of the lake is very irregular, several long arms extending out approximately at right angles to the central part.

The United States Geological Survey in 1883 estimated the area at 125 square miles, but its present area probably does not exceed 60 square miles. Its former maximum depth of 56 feet has now been reduced to 18 feet.

The recession of the lake has left its evidence upon its former shores in the form of terraces indicating the old beach lines. Two of these are easily traceable, and many smaller and less distinct may be found (Figs. 5 and 6).

FIG. 5. THE "A" BEACH, THE HIGHEST LEVEL OF DEVIL'S LAKE. The highway is cut through the bank at the left. The water came to the foot of this bank. (From Simpson, N. D. G. S. Report for 1909-10.)

The climate of the region in which Devil's Lake lies is characteristic of inland plateaus. The precipitation averages 18 inches. The winters are long and cold, with a minimum temperature of —44° F.; the summers short, with generally cool nights and warm days, the thermometer occasionally reaching 100° F. in the shade. Many cool days occur in summer, however, frost in June and August, while unusual, being by no means unknown. Devil's Lake is ice-bound from the middle of

November to the middle of April, the ice commonly reaching a thickness of three feet. After breaking in the spring it is driven about the lake with great force by the high winds characteristic of the region, which occasionally reach a velocity of sixty miles an hour, and it is through this ice action in considerable measure that the rock "piles" are formed.

FIG. 6. THE SHORE OF DEVIL'S LAKE, showing recent beach lines (indicated by the zones of plant growth), and a sand spit formed by recession of the lake level. (Young, photo.)

As a result of the recession of the lake a great concentration in its salt content is occurring. The present amount of total solids is about 15,000 parts per million, consisting largely of the sulphates of sodium and magnesium, and sodium chloride. The specific gravity is 1.014 and the osmotic pressure 6.5 atmospheres.[2] These figures vary somewhat from time to time dependent on the lake level. In spite of its alkaline character the water is drunk to some extent by cattle. The chemical character of the various parts into which the lake is divided varies widely, dependent upon different factors, such as date of separation from the main body, character of shores with consequent amount of run off, and depth.

To the physiographer Devil's Lake is of great interest, showing as it does so clearly the evidence of its past history, with the same processes in action at present; but to the biologist it is of even greater interest by reason of the changes in its inhabitants, which are accompanying the changes in its physical and chemical condition.

Previous to 1883 the lake swarmed with pickerel, but shortly subsequent to that date and coincident with a rapid decrease in the lake level, they suddenly disappeared.

[2] These data refer to the main part of Devil's Lake.

In order to ascertain, if possible, the cause of their disappearance, to investigate the possibility of restocking the lake with fish and to study the many problems of scientific interest presented by it as well as by other waters in the state, the legislature of 1909 made an appropriation of $5,000 for the construction of a building, beside $3,000 annually for maintenance.

The building (Fig. 7) is a tasteful two-story structure, the lower story being constructed of boulders from the lake shore

FIG. 7. NORTH DAKOTA BIOLOGICAL STATION AT DEVIL'S LAKE. (From Brannon, Report of the Biological Station for 1909-10.)

and the upper of frame covered with stucco. It contains a small hatchery equipped for handling several million eggs at one time, a small museum of local animals, a large assembly room, five rooms for private workers, beside a director's office, and a chemical laboratory.

The equipment, while simple, is adequate for the purposes for which it is designed.

The investigations of the station have covered three main lines—experiments in restocking the lake with fish, studies on the effects of environment and isolation on Crustacea and studies of the plankton and its environment.

For a number of years sporadic attempts at stocking the lake have been made by residents of the vicinity, and in 1907 the U. S. Bureau of Fisheries sent a field party to study the lake and report upon the feasibility of planting fish in it. They found that several species of fish could live in the lake for a number of weeks.[3]

[3] See Pope, T. E. B., "Devil's Lake, North Dakota." Bur. of Fish. Doc. 634, 1907.

Since the establishment of the station experiments in restocking have been carried on by the former director, Dr. M. A. Brannon and by the writer.

These experiments have shown that when conditions are favorable—if the fish are in good condition on arrival and the water is cool (less than 65° F.), it is possible to introduce them directly into lake water with very little loss. On the contrary, when the fish suffer from high temperature or insufficient oxygen in transit, and reach the lake in poor condition better results are obtained by holding them for several days in concrete tanks, where they are gradually acclimatized to the lake water. This method also appears to be safer for the very young fish (six to eight weeks old), while older fish (one year or more) will bear direct transfer if conditions are favorable.

Beside the experiments with fingerlings and older fish, a large number of the pike perch and yellow perch have been hatched and transferred to the lake. While under observation in the hatchery jars or troughs, a large percentage of the eggs hatch nicely and the young fish are active and appear perfectly healthy. Owing to difficulties in keeping these very small fish in aquaria or cages it has not yet been possible to hold them for observation for any considerable time after hatching, but it is probable that some means may be devised for doing this in future. The experiments have been conducted mainly with yellow perch, both because of its ability to live in the lake and the available supply; but it has been found that other species (catfish, black bass, rainbow and steel head trout and pike perch) will under favorable conditions live in the lake.

These experiments are of great interest in their bearing on the ability of fish to withstand changes in the density of water.

The problem of the transfer of organisms between media of different densities opens up a wide field of investigation and has led to much experiment thus far and to many conflicting results. What are the factors involved in such transfer? Is it purely a question of osmotic pressure, or of chemical action between the body fluids and the surrounding media? What is the rôle of salts in the preservation of life? Do they act upon the organism independently of each other or is there a combined effect? Is it possible to accustom all organisms to changes in density of their surrounding media, or are some of them closely circumscribed in this respect, and what are the limits of such adaptability? If differences in this respect exist in different organisms, to what are they due? What is the relative effect of sudden and gradual changes in density? These are some of the many questions involved in this problem.

The experiments at Devil's Lake have shown clearly that many species of fish can withstand changes in density of about .011, that the ability of the fish to withstand such changes is largely dependent on the temperature and on the condition of the fish at the time, and that marked differences exist between individual fish in this respect.

The reasons for the disappearance of the pickerel can not be stated with certainty. Coincident with their disappearance a marked decrease in lake level took place. This cut off the coulée coming in from the lakes northward in which the pickerel bred. Previous to their disappearance they were taken from the lake in large numbers without restriction, and this fact coupled with the loss of their breeding grounds is sufficient in some measure to explain their disappearance. It does not, however, explain the suddenness of their disappearance, which, according to all reports, took place between 1885 and 1889. It is probable, therefore, that some epidemic was the third factor in their reduction. Regarding this it is of course impossible to obtain definite information now.

A second line of work conducted by the station is the study of the variation produced in organisms by changes in the physico-chemical character of their environment and by isolation, using for this purpose mainly the copepod *Diaptomus* (Fig. 8).

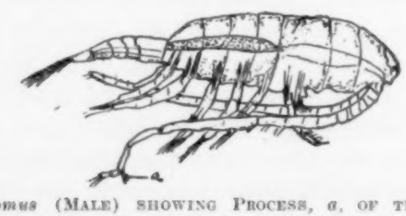

FIG. 8. *Diaptomus* (MALE) SHOWING PROCESS, *a*, OF THE RIGHT ANTENNA. The length of this process, together with that of the antenna and the body, shows marked differences in inhabitants of different ponds, as the result of differences in environment and of isolation. Magnified 50 diameters. (Moberg, del.)

A large number of these from ten of the separate parts of the lake collected in all seasons of the year have been carefully measured and compared. The following data have been chosen for such comparison: length of body, antennæ and process of right antenna in the male.

This study has shown clearly a distinct variation in all of these dimensions as the result of such changes in environment, the length of the process of the antenna of the male varying directly, while the length of the antenna varies inversely as the length of body.

These results are consistent with those of many other

workers respecting the influence of environment and isolation in modifying organisms. They open up a wide field of further observation and experiment, such as the transfer of organisms from one pond to another to determine whether the differences are constant or reversible; the gradual increase in density of the water to determine how soon such increase shows its effect, and whether it has any other effects in influencing the sex and number of offspring in successive generations, etc.; a comparison of the differences found between organisms in lakes far distant and those in the Devil's Lake complex; a study of the developing organisms in the various ponds to determine whether the larvæ show differences comparable with those of the adults; these are some of the many interesting and important problems waiting to be solved. Such questions, while seemingly of interest only to the specialist, are nevertheless of profound importance to all of us, for they seek to answer in some measure the ever-vexing question of "nature vs. nurture." If it is reasonable to believe that all protoplasm is fundamentally alike, however widely it may differ in its manifold forms and reactions, then the solution of this question of the relative part played by heredity and environment in the development of even so humble a creature as a little shrimp-like animal about one twentieth of an inch in length, should aid in answering the same question in human development. The fact that in the Devil's Lake complex we have in many cases an exact, and in all a fairly accurate record of the time that nature has been performing these isolation experiments for us, and that we have ready made, as it were, a large number of experimental ponds in which to conduct further experiments of our own, renders this region an unusually favorable one in which to study the problem.

The plankton, the minute free-swimming organisms, in the lake has been extensively studied in its relation to its environment. These studies comprise over 800 collections from all parts of the main body of the lake and several of the outlying ponds. These have been taken both by day and by night, at all times of year, including midwinter. The organisms contained in these collections are now being counted, after which a comprehensive report will be prepared. Coincident with many of these collections determinations of temperature, dissolved gases, etc., have been made. Studies of the plankton have brought out clearly the interesting fact that these minute organisms frequently occur in swarms, the causes of which are not at present clear. In two regions separated by only a few feet may

occur immense numbers, especially of the cladoceran Moina, while the intervening areas may be comparatively free from it. Differences as great as 400 per cent. may occur between two places seemingly alike in every respect. So far as can be determined, there is no difference either in chemistry, physics or food supply to determine these differences. Their explanation must therefore be sought in some as yet obscure biological factor.

Some preliminary studies have also been made of the Red and Missouri rivers and of other waters in North Dakota, but the main activities of the station have been confined to Devil's Lake and its adjacent waters.

The fauna and flora of the lake are interesting both in respect to what they do, and do not contain. The only vertebrate inhabitants are the stickleback, the leopard frog and the salamander *Amblystoma*. Among the invertebrates the crustaceans, insects and rotifers are each represented by several species. One of the latter *Brachionus,* named from its habitat *satanicus* by Mr. Rousselet of London, is new to science. A few extinct mollusks occur and at least one arachnid, but the cœlenterates, sponges, polyzoans and annelids are apparently entirely absent, and thus far but one free-living flatworm has been found. Nematodes on the contrary are common, and include several species as yet only partially determined. The animal phylum most largely represented is the protozoa. These include chiefly ciliates and flagellates, many of which are as yet indeterminate and probably represent new species. The rhizopods are poorly represented, *Arcella vulgaris* being the only one which occurs at all commonly. This is the more remarkable in view of the fine layer of ooze covering the lake floor. The fact that this layer is occasionally lacking in free oxygen may explain their absence, but Juday's observations[4] on animals living in water lacking free oxygen, and the presence of several other protozoa in the ooze in Devil's Lake, render this explanation somewhat questionable. One of the commonest animals in the lake, the midge *Chironomus,* occurs as a larva exclusively in this ooze.

The ditch grass (*Ruppia*) grows abundantly in the shallower parts of the lake, forming a tangled mass, which in some places prevents navigation with power boats. There are many species of unicellular algæ; some of which, especially the blue-greens, are very abundant. It is difficult to assign to any one

[4] Juday, C., "Some Aquatic Animals that Live under Anærobic Conditions," *Trans. Wis. Acad. Sci.*, XVI., p. 11.

group of plants the most important part in the life of the lake, although the diatoms with some fifty species take first place in respect to variety and play a very important part as food for the animals.

The busiest part of the lake, biologically speaking, is the *Ruppia* zone which occurs in depths of from two to five feet. Here is the nesting place of the stickleback. Attached to the *Ruppia* are masses of the filamentous green alga *Cladophora*, while to this again are attached numerous sessile diatoms and protozoans. Many free-swimming protozoans, rotifers, nemaodes and copepods also occur here; some by chance as they are driven hither and yon by the currents in the lake, others finding favorable shelter in the tangled mass of *Ruppia* and *Cladophora*, and seldom occurring elsewhere.

The rocky islands are the breeding homes of cormorants, ducks and terns, while many other species of water fowl breed abundantly in the marshes, which in some places occupy the old lake bottom. The cormorant colony on "Bird Island," as it is known, is one of the most interesting places about the lake

FIG. 9. BIRD ISLAND IN DEVIL'S LAKE, the home of the double-crested cormorant, whose nests may be seen among the rocks. (Young, photo.)

(Fig. 9). On the approach of the intruder the old birds, and such of the young as are able, scramble off into the water, while the birds which are too young to leave the nest voice their

protests in inarticulate squawking, at the same time disgorging masses of sticklebacks and young salamanders, which form their staple diet. The nests, rude piles of sticks, are crowded together among the rocks. After the breeding season gulls, ducks and terns gather in flocks about the lake, and together with migrant phalarope and sandpipers form a busy and restless population. Some of the flocks of ducks are so large that as they take wing they make a sound like rushing water.

On the southern shore is a long low ridge of morainic hills, the highest point of which is named "Sully's Hill" after General Sully, the old Indian fighter (Fig. 10). The major part of

FIG. 10. DEVIL'S LAKE, shore strewn with glacial boulders in fore-ground. Sully's Hill National Park site in back-ground. (Young, photo.)

this hill which is some three miles long has been set aside as a national park and fenced in for the retention of wild animals (elk, deer, bear, etc.) with which it is planned to stock it.

About two miles to the west of Sully's Hill is the old frontier Fort Totten, now used as an Indian school, while in wretched "shacks" scattered over the hills on the reservation still live some of the old warriors, who in days gone by hunted the buffalo and the white man over the vast plains of the Dakotas.

THE COMPLEXITY OF THE CHEMICAL ELEMENTS, II

By Professor FREDERICK SODDY, M.A., F.R.S.

THE PERIODIC LAW AND RADIOACTIVE CHANGE

THE second line of advance interprets the periodic law. It began in 1911 with the observation that the product of an α-ray change always occupied a place in the periodic table two places removed from the parent in the direction of diminishing mass, and that in subsequent changes where α-rays are not expelled the product frequently reverts in chemical character to that of the parent, though its atomic weight is reduced 4 units by the loss of the α-particle, making the passage across the table curiously alternating. Thus the product of radium (Group II.) by an α-ray change is the emanation in the zero group, of ionium (Group IV.), radium, and so on, while, in the thorium series, thorium (Group IV.) produces by an α-ray change mesothorium-I (Group II.), which, in subsequent changes in which no α-rays are expelled, yields radio-thorium, back in Group IV. again.[1] Nothing at that time could be said about β-ray changes. The products were for the most part very short-lived and imperfectly characterized chemically, and several lacunæ still existed in the series masking the simplicity of the process. But early in 1913 the whole scheme became clear, and was pointed out first by A. S. Russell, in a slightly imperfect form, independently by K. Fajans from electro-chemical evidence, and by myself, in full knowledge of Fleck's results, still for the most part unpublished, all within the same month of February. It was found that, making the assumption that uranium-X was in reality two successive products giving β-rays, a prediction Fajans and Göhring proved to be correct within a month, and a slight alteration in the order at the beginning of the uranium series, every α-ray change produced a shift of place as described, and every β-ray change a shift of one place in the opposite direction. Further and most significantly, when the successive members of the three disintegration series were put in the places in the table dictated by these two rules, it was found

[1] "Chemistry of the Radio-Elements," p. 29, first edition, 1911.

that all the elements occupying the same place were those which had been found to be non-separable by chemical processes from one another, and from the element already occupying that place, if it was occupied, before the discovery of radioactivity. For this reason the term "isotope" was coined to express an element chemically non-separable from the other, the term signifying "the same place."

So arranged, the three series extended from uranium to thallium, and the ultimate product of each series occupied the place occupied by the element lead. The ultimate products of thorium should, because six α-particles are expelled in the process, have an atomic weight 24 units less than the parent, or about 208. The main ultimate product of uranium, since eight α-particles are expelled in this case, should have the atomic weight 206. The atomic weight of ordinary lead is 207.2, which made it appear very likely that ordinary lead was a mixture of the two isotopes, derived from uranium and thorium. The prediction followed that lead, separated from a thorium mineral, should have an atomic weight about a unit higher, and that separated from uranium minerals about a unit lower, than the atomic weight of common lead, and in each case this has now been satisfactorily established.

The Atomic Weight of Lead from Radioactive Minerals

It should be said that Boltwood and also Holmes had, from geological evidence, both decided definitely against it being possible that lead was a product of thorium, because thorium minerals contain too little lead, in proportion to the thorium, to accord with their geological ages. Whereas, the conclusion that lead was the ultimate product of the uranium series had been thoroughly established by geological evidence, and has been the means, in the hands of skilful investigators, of ascertaining geological ages with a degree of precision not hitherto possible. Fortunately I was not deterred by the *non possumus*, for it looks as if everybody was right! An explanation of this paradox will later be attempted. In point of fact, there are exceedingly few thorium minerals that do not contain uranium, and since the rate of change of uranium is about 2.6 times that of thorium, one part of uranium is equal as a lead-producer to 2.6 parts of thorium. Thus Ceylon thorianite, one of the richest of thorium minerals, containing 60 to 70 per cent. of ThO_2, may contain 10 to 20 and even 30 per cent. of U_3O_8, and the lead from it may be expected to consist of very similar quan-

tities of the two isotopes, to be in fact very similar to ordinary lead. I know of only one mineral which is suitable for this test. It was discovered at the same time as thorianite, and from the same locality—Ceylon thorite, a hydrated silicate containing some 57 per cent. of thorium and 1 per cent. of uranium only. In the original analysis no lead was recorded, but I found it contained 0.4 per cent., which, if it were derived from uranium only, would indicate a very hoary ancestry, comparable, indeed, with the period of average life of uranium itself. On the other hand, if (1) all the lead is of radioactive origin, (2) is stable, and (3) is derived from both constituents, as the generalization being discussed indicated, this 0.4 per cent. of lead should consist 95.5 per cent. of the thorium isotope and 4.5 per cent. of the uranium isotope. Thorite thus offered an extremely favorable case for examination.

In preliminary experiments in conjunction with H. Hyman, in which only a gram or less of the lead was available, the atomic weight was found relatively to ordinary lead to be perceptibly higher, and the difference, rather less than one half per cent., was of the expected order.

I was so fortunate as to secure a lot of 30 kilos of this unique mineral, which was first carefully sorted, piece by piece, from admixed thorianite and doubtful specimens. From the 20 kilos. of first grade thorite, the lead was separated, purified, reduced to metal, and cast *in vacuo* into a cylinder, and its density determined together with that of a cylinder of common lead similarly purified and prepared. Sir Ernest Rutherford's theory of atomic structure, to be dealt with in the latter part of this discourse, and the whole of our knowledge as to what isotopes were, made it appear probable that their atomic volumes, like their chemical character and spectra, should be identical, and therefore that their density should be proportional to their atomic weight. The thorite lead proved to be 0.26 per cent. denser than the common lead. Taking the figure 207.2 for the atomic weight of common lead, the calculated atomic weight of the specimen should be 207.74.

The two specimens of lead were fractionally distilled *in vacuo*, and a comparison of the atomic weights of the two middle fractions made by a development of one of Stas's methods. The lead was converted into nitrate in a quartz vessel, and then into chloride by a current of hydrogen chloride, in which it was heated at gradually increasing temperature to constant weight. Only single determinations have been done, and they gave the values 207.20 for ordinary lead, and 207.694

for the thorite lead, figures that are in the ratio of 100 to 100.24. This therefore favored the conclusion that the atomic volume of isotopes is constant.

At the request of Mr. Lawson, interned in Austria, and continuing his researches at the Radium Institut under Professor Stefan Meyer, the first fraction of the distilled thorite lead was sent him, so that the work could be checked. He reports that Professor Hönigschmid has carried through an atomic weight determination by the silver method, obtaining the value 207.77 ± 0.014, as the mean of eight determinations. Hence, the conclusion that the atomic weight of lead derived from thorite is higher than that of common lead has been put beyond reasonable doubt.

Practically simultaneously with the first announcement of these results for thorium lead, a series of investigations were published on the atomic weight of lead from uranium minerals, by T. W. Richards and collaborators at Harvard, Maurice Curie in Paris, and Hönigschmid and collaborators in Vienna, which show that the atomic weight is lower than that of ordinary lead. The lowest result hitherto obtained is 206.046, by Hönigschmid and Mlle. Horovitz for the lead from the very pure crystallized pitchblende from Morogoro (German East Africa), whilst Richards and Wadsworth obtained 206.085 for a carefully selected specimen of Norwegian clevite. Numerous other results have been obtained, as, for example, 206.405 for lead from Joachimsthal pitchblende, 206.82 for lead from Ceylon thorianite, 207.08 for lead from monazite, the two latter being mixed uranium and thorium minerals. But the essential proportion between the two elements has not, unfortunately, been determined. Richards and Wadsworth have also examined the density of their uranium lead. In every case they have been able to confirm the conclusion that the atomic volume of isotopes is constant, the uranium lead being as much lighter as its atomic weight is smaller than common lead. Many careful investigations of the spectra of these varieties of lead show that the spectrum is absolutely the same so far as can be seen.

Thorium and Ionium

A second quite independent case of a difference in atomic weight between isotopes has been established. It concerns the isotopes thorium and ionium, and it is connected in an important way with the researches which, on two previous occasions, I have given an account of here, the researches on the

growth of radium from uranium, which have been in progress now for fourteen years. It is the intervention of ionium and its very long period of life which has made the experimental proof of the production of radium from uranium such a long piece of work. Previously only negative results were available. One could only say, from the smallness of the expected growth of radium, that the period of average life of ionium must be at least 100,000 years, forty times longer than that of radium, and, therefore, that there must be at least forty times as much ionium by weight as radium in uranium minerals, or at least 13.6 grams per 1,000 kilos of uranium. Since then further measurements, carried out by Miss Hitchins last year, have shown definitely for the first time a clear growth of radium from uranium in the largest preparation, containing 3 kilos of uranium, and this growth, as theory requires, is proceeding according to the square of the time. In three years it amounted to 2×10^{-11} grams of radium, and in six years to just four times this quantity. From this result it was concluded that the previous estimate of 100,000 years for the period of ionium, though still of the nature of a minimum rather than a maximum, was very near to the actual period.

Joachimsthal pitchblende, the Austrian source of radium, contains only an infinitesimal proportion of thorium. An ionium preparation separated, by Auer von Welsbach, from 30 tons of this mineral, since no thorium was added during the process, was an extremely concentrated ionium preparation. The atomic weight of ionium—calculated by adding to the atomic weight of its product, radium, four for the α-particle expelled in the change—is 230, whereas that of thorium, its isotope, is slightly above 232. The question was whether the ionium-thorium preparation would contain enough ionium to show the difference. Hönigschmid and Mlle. Horovitz have made a special examination of the point, first redetermining as accurately as possible the atomic weight of thorium and then that of the thorium-ionium preparation from pitchblende. They found 232.12 for the atomic weight of thorium, and by the same method 231.51 for that of the ionium-thorium. A very careful and complete examination of the spectra of the two materials showed for both absolutely the same spectrum and a complete absence of impurities.

If the atomic weight of ionium is 230, the ionium-thorium preparation must, from its atomic weight, contain 30 per cent. of ionium and 70 per cent. of thorium by weight. Professor Meyer has made a comparison of the number of α-particles

given per second by this preparation with that given by pure radium, and found it to be in the ratio of 1 to 200. If 30 per cent. is ionium, the activity of pure ionium would be one sixtieth of that of pure radium, its period some sixty times greater, or 150,000 years. This confirms in a very satisfactory manner our direct estimate of 100,000 years as a minimum, and incidentally raises rather an interesting question.

My direct estimate involves directly the period of uranium itself, and if the value accepted for this is too high, that for the ionium will be correspondingly too low. Now, last week, Professor Joly was bringing before you, I believe, some of his exceedingly interesting work on pleochroic halos, from which he has grounds for the conclusion that the accepted period of uranium may be too long. But since I obtained, for the period of ionium, a minimum value two thirds of that estimated by Meyer from the atomic weight, it is difficult to believe that the accepted period of uranium can have been overestimated by more than 50 per cent. of the real period. The matter could be pushed to a further conclusion if it were found possible to estimate the percentage of thorium in the thorium-ionium preparation, a piece of work that ought not to be beyond the resources of radio-chemical analysis. This would then constitute a check on the period of uranium as well as on that of ionium. Such a direct check would be of considerable importance in the determination of geological ages.

The period of ionium enables us to calculate the ratio, between the weights of ionium and uranium in pitchblende, as 17.4 to 10^9, and the doctrine of the non-separability of isotopes leads directly to the ratio, between the thorium and uranium in the mineral, as 41.7 to 10^9. This quantity of thorium is, unfortunately, too small for direct estimation. Otherwise it would be possible to devise a very strict test of the degree of non-separability. As it is, the work is sufficiently convincing. Thirty tons of a mineral containing a majority of the known elements in detectable amount, in the hands of one whose researches in the most difficult field of chemical separation are world-renowned, yield a preparation of the order of one millionth of the weight of the mineral, which can not be distinguished from pure thorium in its chemical character. Any one could tell in the dark that it was not pure thorium, for its α-activity is 30,000 times greater than that of thorium. This is then submitted to that particular series of purifications designed to give the purest possible thorium for an atomic weight determination, and it emerges without any separation of the

ionium, but with a spectrum identical with that of a control specimen of thorium similarly purified. The complete absence of impurities in the spectrum shows that the chemical work has been very effectively done, and the atomic weight shows that it must contain 30 per cent. by weight of the isotope ionium, a result which agrees with its α-activity and the now known period of the latter.

Determination of Atomic Weights

The results enumerated thus prove that the atomic weight can no longer be regarded as a natural constant, or the chemically pure element as a homogeneous type of matter. The latter may be, and doubtless often is, a mixture of isotopes varying in atomic weight over a small number of units, and the former then has no exact physical significance, being a mean value in which the proportions of the mixture as well as the separate atomic weights are both unknown. New ideals emerge and old ones are resuscitated by this development. There may be, after all, a very simple numerical relation between the true atomic weights. The view that seems most probably true at present is that while hydrogen and helium may be the ultimate constituents of matter in the Proutian sense, and the atomic weights therefore approximate multiples of that of hydrogen, small deviations, such as exist between the atomic weights of these two constituent elements themselves, may be due to the manner in which the atom is constituted, in accordance with the principle of mutual electro-magnetic mass, developed by Silberstein and others. The electro-magnetic mass of two charges in juxtaposition would not be the exact sum of the masses when the charges are separated. The atomic weight of hydrogen is 1.0078 in terms of that of helium as 3.99, and that the latter is not exactly four times the former may be the expression of this effect. Harkins and Wilson have recently gone into the question with some thoroughness, and the conclusion of most interest in the present connection, which appears to emerge, is in favor of regarding most of the effect to occur in the formation of helium from hydrogen, and very little in subsequent aggregations of the helium. In the region of the radio-elements, where we have abundant examples of the expulsion of helium atoms as α-particles, it seems as if we could almost safely neglect this effect altogether. Thus radium has the atomic weight almost exactly 226, and the ultimate product almost exactly 206, showing that in 5 α- and 4 β-ray changes the

mean effect is nil, and the atomic weights are moreover integers in terms of oxygen as 16, or helium 4. It is true that the atomic weights of both thorium and uranium are between 0.1 and 0.2 greater than exact integers, but it is difficult to be sure that this difference is real.

When, among the light elements, we come across a clear case of large departure from the integral value, such as magnesium 24.32 and chlorine 35.46, we may reasonably suspect the elements to be a mixture of isotopes. If this is true for chlorine, it suggests a most undesirable feature in the modern practice of determining atomic weights. More and more the one method has come to be relied upon: the preparation of the chloride of the element and the comparison of its weight with that of the silver necessary to combine with the chlorine, and with the weight of the silver chloride formed.

Almost the only practical method, and that a very laborious and imperfect one, which may be expected to resolve a mixture of isotopes, is by long-continued fractional gaseous diffusion, which is likely to be the more effective the lower the atomic weight. Assume, for example, chlorine were a mixture of isotopes of separate atomic weights 34 and 36, or 35 and 36. The 34 isotope would diffuse some 3 per cent. faster than the 36, and the 35 some 1.5 per cent. faster.

The determination of the atomic weight of chlorine in terms of that of silver has reached now such a pitch of refinement that it should be able to detect a difference in the end fractions of the atomic weight of chlorine, if chlorine or hydrogen chloride were systematically subjected to diffusion. It is extremely desirable that such a test of the homogeneity of this gas should be made in this way.

Clearly a change must come in this class of work. It is not of much use starting with stuff out of a bottle labeled "purissimum" or "garantirt," and in determining to the highest possible degree of accuracy the atomic weight of an element of unknown origin. The great pioneers in the subject, like Berzelius, were masters of the whole domain of inorganic chemistry, and knew the sources of the elements in nature first-hand. Their successors must revert to their practise and go direct to nature for their materials, must select them carefully with due regard to what geology teaches as to their age and history, and, before carrying out a single determination, they must analyze their actual raw materials completely, and know exactly what it is they are dealing with. Much of the work on the atomic weight of lead from mixed minerals is useless, for

failure to do this. They must rely more on the agreement, or disagreement, of a great variety of results by methods as different and for materials as different as possible, rather than on the result of a single method pushed to the limit of refinement, for an element provisionally purified by a dealer from quite unknown materials. The preconceived notion, that the results must necessarily agree if the work is well done, must be replaced by a system of cooperation between the workers of the world checking each other's results for the same material. A year ago any one bold enough to publish atomic weight determinations, which were not up to the modern standards of agreement among themselves, would have been regarded as having mistaken his vocation. If these wider ideals are pursued, all the labor that has been lavished in this field, and which now seems to have been so largely wasted, may possibly bear fruit, and where the newer methods fail, far below the narrow belt of elements which it is possible to watch changing, the atomic weight worker may be able to pick up the threads of the great story. No doubt it is writ in full in the natural records preserved by rock and mineral, and the evidence of the atomic weights may be able to carry to a triumphant conclusion the course of elementary evolution, of which as yet only an isolated chapter has been deciphered.

THE STRUCTURE OF THE ATOM

The third line of recent advance, which does much to explain the meaning of the isotopes and the periodic law, starts from Sir Ernest Rutherford's nuclear theory of the atom, which is an attempt to determine the nature of atomic structure, which again is the necessary preliminary to the understanding of the third aspect in which the elements are or may be complex. That uranium and thorium are built up of different isotopes of lead, helium and electrons is now an experimental fact, since they have been proved to change into these constituents. But the questions how they are built up, and what is the nature of the non-radioactive elements, which do not undergo changes, remain unsolved.

Professor Bragg showed in 1905 that the α-particles can traverse the atoms of matter in their path almost as though they were not there. As far as he could tell, and the statement is still true of the vast majority of α-particles colliding with the atoms of matter, the α-particle ploughs its way straight through, pursuing a practically rectilinear course, losing

slightly in kinetic energy at each encounter with an atom, until its velocity is reduced to the point at which it can no longer be detected. From that time, the α-particle became, as it were, a messenger that could penetrate the atom, traverse regions which hitherto had been bolted and barred from human curiosity, and on reemerging could be questioned, as it was questioned, effectively by Rutherford, with regard to what was inside. Sir J. J. Thomson, using the electron as the messenger, had obtained valuable information as to the number of electrons in the atom, but the massive material α-particle alone can disclose the material atom. It was found that, though the vast majority of α-particles reemerge, from their encounters with the atoms, practically in the same direction as they started, suffering only slight hither and thither scattering due to their collisions with the electrons in the atom, a minute proportion of them suffer very large and abrupt changes of direction. Some are swung round, emerging in the opposite to their original direction. The vast majority, that get through all but undeflected, have met nothing in their passage save electrons, 8,000 times lighter than themselves. The few that are violently swung out of their course must have been in collision with an exceedingly massive nucleus in the atom, occupying only an insignificant fraction of its total volume. The atomic volume is the total volume swept out by systems of electrons in orbits of revolution round the nucleus, and beyond these rings or shells guarding the nucleus it is ordinarily impossible to penetrate. The nucleus is regarded by Rutherford as carrying a single concentrated positive charge, equal and opposite to that of the sum of the electrons.

Chemical phenomena deal almost certainly with the outermost system of detachable or valency electrons alone, the loss or gain of which conditions chemical combining power. Light spectra originate probably in the same region, though possibly more systems of electrons than the outermost may contribute, while the X-rays and γ-rays seem to take their rise in a deep-seated ring or shell around the nucleus. But mass phenomena, all but an insignificant fraction, originate in the nucleus.

In the original electrical theory of matter, the whole mass of the atom was attributed to electrons, of which there would have been required nearly 2,000 times the atomic weight in terms of hydrogen as unity. With the more definite determination of this number, and the realization that there were only about half as many as the number representing the atomic weight, it was clear that all but an insignificant fraction of the

mass of the atom was accounted for. In the nuclear hypothesis this mass is concentrated in the exceedingly minute nucleus. The electro-magnetic theory of inertia accounts for the greater mass if the positive charges that make up the nucleus are very much more concentrated than the negative charges which constitute the separate electrons. The experiments on scattering clearly indicated the existence of such a concentrated central positive charge or nucleus.

The mathematical consideration of the results of α-ray scattering, obtained for a large number of different elements, and for different velocities of α-ray, gave further evidence that the number of electrons, and therefore the + charge on the nucleus, is about half the number representing the atomic weight. But van der Broek, reviving an isolated suggestion from a former paper full of suggestions on the periodic law, which were, I think, in every other respect at fault, suggested that closer agreement with the theory would be obtained if the number of electrons in the atom, or the nuclear charge, was the number of the place the element occupied in the periodic table. This is now called the atomic number, that of hydrogen being taken as 1, helium 2, lithium 3, and so on to the end of the table, uranium 92, as we now know. For the light elements, it is practically half the atomic weight; for the heavy elements, rather less than half.

I pointed out this accorded well with the law of radioactive change that had been established to hold over the last thirteen places in the periodic table. This law might be expressed as follows: The expulsion of the α-particle carrying two positive charges lowers the atomic number by two, while the expulsion of the β-particle, carrying a single negative charge, increases it by one. In ignorance of van der Broek's original suggestion, I had, in representing the generalization, shown the last thirteen places as differing by unit by unit in the number of electrons in the atom.

Then followed Moseley's all-embracing advance, showing how from the wave-lengths of the X-rays, characteristic of the elements, this conception explained the whole periodic table. The square roots of the frequency of the characteristic X-rays are proportional to the atomic numbers. The total number of elements existing between uranium and hydrogen could thus be determined, and it was found to be ninety-two, only five of the places being vacant. The "exceptions" to the periodic law, such as argon and potassium, nickel and cobalt, tellurium and iodine, in which an element with higher atomic weight precedes

instead of succeeds one with lower, was confirmed by the determination of the atomic numbers in every case. From now on, this number, which represents the + charge on the nucleus, rather than the atomic weight, becomes the natural constant which determines chemical character, light and X-ray spectra, and, in fact, all the properties of matter, except those that depend directly on the nucleus—mass and weight on the one hand, and radioactive properties on the other.

What, then, were the isotopes on this scheme? Obviously they were elements with the same atomic number, the same *net* charge on the nucleus, but with a differently constituted nucleus. Take the very ordinary sequence in the disintegration series, one α- and two β-rays being successively expelled in any order. Two + and two — charges have been expelled, the *net* charge of the nucleus remains the same, the chemical character and spectrum the same as that of the first parent, but the mass is reduced 4 units because a helium atom, or rather nucleus, has been expelled as an α-particle. The mass depends on the *gross* number of + charges in the nucleus, chemical properties on the difference between the gross numbers of + and — charges. But the radioactive properties depend not only on the gross number of charges but on the constitution of the nucleus. We can have isotopes with identity of atomic weight, as well as of chemical character, which are different in their stability and mode of breaking up. Hence we can infer that this finer degree of isotopy may also exist among the stable elements, in which case it would be completely beyond our present means to detect. But when transmutation becomes possible such a difference would be at once revealed.

The case is not one entirely of academic interest, because it is probable that the reconciliation of the conflicting views of the geologists and chemists, who concluded that lead was not the ultimate product of thorium, and those who by atomic weight demonstrations on the lead have shown that it is, depends probably on this point.

As has long been known, thorium-C, an isotope of bismuth, disintegrates dually. For 35 per cent. of the atoms disintegrating, an α-ray is expelled followed by a β-ray. For the remaining 65 per cent. the β-ray is first expelled and is followed by the α-ray. The two products are both isotopes of lead, and both have the same atomic weight, but they are not the same. More energy is expelled in the changes of the 65 per cent. fraction than in those of the 35 per cent. Unless they are both

completely stable a difference of period of change is to be anticipated.

The same thing is true for radium-C, but here all but a very minute proportion of the atoms disintegrating follow the mode followed by the 65 per cent. in the case of thorium-C. The product in this case, radium-D, which, of course, is also an isotope of lead, with atomic weight 210, is *not* permanently stable, though it has a fairly long period, 24 years. The other product is not known to change further, but then, even if it did, it is in such small quantity that it is doubtful whether the change would have been detected. But, so far as is known, it forms a stable isotope of lead of atomic weight 210, formed in the proportion of only 0.03 per cent. of the whole.

Now the atomic weight evidence merely shows that *one* of the two isotopes of lead formed from thorium is stable enough to accumulate over geological epochs, and it does not necessarily follow that both are. Dr. Arthur Holmes has pointed out to me that the analysis I gave of the Ceylon thorite leads to a curiously anomalous value for the age of the mineral. The quantity of thorium lead per gram of thorium is 0.0062, and this, divided by the rate at which the lead is being produced, 4.72×10^{-11} gram of lead per gram of thorium per year, gives the age as 131 million years. But a Ceylon pitchblende, with uranium 72.88 per cent. and lead 4.65 per cent., and ratio of lead to uranium as 0.064, gives the age as 512 million years. Dr. Holmes regards the two minerals as likely to be of the same age, and the pitchblende to be, of all the Ceylon results, the one most trustworthy for age measurement.

If we suppose that, as in the case of radium-D, the 65 per cent. isotope of lead derived from thorium is *not* stable, and that only the 35 per cent. isotope accumulates, the age of the mineral would be 375 million years, which the geologists are likely to consider much more nearly the truth. But the most interesting point is that, if we take the atomic weight of the lead isotope derived from uranium as 206.0, and that derived from thorium as 208.0, and calculate the atomic weight of the lead in Ceylon thorite, assuming it to consist entirely of uranium lead and of only the 35 per cent. isotope from thorium, we get the value 207.74, which is exactly what I found from the density, and what Professor Hönigschmid determined (207.77).

The question remains, if this is what occurs, what does this unstable lead change into? If an α-particle were expelled mercury would result, or if a β-particle bismuth, two elements of

which I could find no trace in the lead group separated from the whole 20 kilos of mineral. But if an α- and a β-particle were both expelled, the product would be thallium, which is present in amount small but sufficient for chemical as well as spectroscopic characterization. If the process of disintegration does proceed as suggested, it should be possible to trace it, for this particular lead should give a feeble specific α- or β-radiation, in addition, of course, to that due to other lead isotopes. So far it has not been possible to test this. In the meantime, the explanation offered is put forward provisionally as being consistent with all the known evidence.

Looking for a moment in conclusion at the broader aspects of the new ideas of atomic structure, it seems that though a sound basis for further development has been roughed out, almost all the detail remains to be supplied. We have got to know the nucleus, but beyond the fact that it is constituted, in heavy atoms, of nuclei of helium and electrons, nothing is known. Whilst as regards the separate shells or rings of electrons which neutralize its charge and are supposed to surround it, like the shells of an onion, we really know nothing yet at all. The original explanation, in terms of the electron, of the periodicity of properties displayed by the elements, still remains all that has been attempted. We may suppose, as we pass through the successive elements in the table, one more electron is added to the outermost ring for each unit increase in the charge on the nucleus, or atomic number, and that when a certain number, 8 in the early part of the table, 18 later, a complete new stable shell or ring forms, which no longer participates directly in the chemical activities of the atom. Thanks, however, to Moseley's work, this now is not sufficiently precise; for we know the exact number of the elements, and the various atomic numbers at which the remarkable changes, in the nature of the periodicity displayed, occur. Any real knowledge in this field will account not only for the two short initial periods, but also for the curious double periodicity later on, in which the abrupt changes of properties in the neighborhood of the zero family alternate with the gradual changes in the neighborhood of the eighth groups. The extraordinary exception to the principle of the whole scheme presented by the rare-earth elements remains a complete enigma, none the less impressive because, beyond them again in the table, the normal course is resumed and continues to the end.

THE PSYCHOLOGY OF CONVICTION[1]

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A NOTABLE contribution of the world convulsion of 1914 and thereafter is to the psychology of conviction. It has been made plain as never before that the strength and directions of men's convictions—authoritatively formulated in loyalties—furnish the decisive motive power of the world's energies. Under this stimulus the need of inquiry into the mental processes that generate and direct convictions becomes increasingly imperative. There can be no question where beginnings lie. The original source of conviction is emotion. In terms of the world's crisis, the *modus vivendi* of nations is still expressible in Mr. Wells's phrase: a "convention between jealousies"; and jealousy is an intense and disturbing emotion. The initial factor in the genesis of conviction is the rivalry between reason and emotion. Convictions are commonly and rightly considered as products of rational consideration; they testify to the distinctive quality of the human mind—conceived and glorified as the instrument of thought, the creator of civilization. In this view the progress of science unfolds as the triumph of reason. Fundamentally it is true that the pattern of conviction is designed and wrought of reason's threads, but not simply so. The design deviates, the workmanship is irregular, as thinking is emotionalized. The wish is father to the thought and breeds true.

The psychology of conviction surveys the play of forces that shape the aims of men, however fine-spun or rough-hewn. The spirit of the survey is analytic; its method utilizes the historic retrospect, studying beliefs that once have lived and flourished, but interprets them by insight into the motives of convictions warmly vital, pragmatically alive, dispensing mingled profit and loss. Living beliefs, cherished and effective, alone supply adequate specimens for study. Their analysis is vivisectional, yet proceeds upon a competent control of established anatomical and physiological relations.

To reach convictions implies an impulse toward thinking; it implies the elementary data of experience and standard

[1] The introductory essay in a volume with this title to appear in 1918.

social environment in which beliefs operate and determine conduct. With these assumed, attention may be focussed at once upon a constant, world-old and ever active factor, which may be called docility, contagion, complacency, imitation, convention —one and all of a nature compact. In this broader view, men's convictions, generation by generation, have been accepted traditionally, as they still are. In every direction of inquiry, beliefs have been embraced and have kept thinking alive, that to later, more enlightened views appear strange, fanciful, and irrational. Most generally, people have believed and continue to believe what they are told and taught to believe. In terms of efficiency this factor in the psychology of conviction dwarfs all others, and may throw them out of perspective. Men of affairs as well as psychologists must continue to reckon with this comprehensive and insistent—whether wise or unwise—imitative-conservative tendency. Its field of operation is wide. In the interpretation of nature and man's place in it, in the intimate communion with animals as quarry, as beast of burden, and as companion, in the regulation of human contacts—of family and tribe, of industry and conquest—in the formulation of myth and the constructions of religion, in the establishment of the social order, the dominant procedure by which uniformity is obtained is that of unquestioning acceptance; as in the practical domain of customs and morals, it is a like-minded tendency to conformity. In regard to these the ordinary man follows responsively, though with growing education more and more responsibly. Penalties are attached to violation, and the taboo rules with universal tyranny. Laws grow in strength and sanction with usage; no phase of thought or action, momentous or trivial, is exempt from the rigidity of the established. The dead hand of the past lays its heavy burden upon man's thinking, permeates the psychology of enlightened as of primitive belief. From a kindred source, in other temper, are derived the lessons of history, the continuity of science, the increasing purposes of men and nations.

By virtue of its comprehensive scope, the factor of conventional conformity may be assumed to be familiar. It occupies the background, constant in its presence, shifting in its setting, against which all other forces, jointly operative, are projected. Similarly important is the fact that in any liberal and modern environment, conformity escapes from a narrow and stereotyped prescription and proscription, and encounters the rivalry of conventions, the contest of opinions, the competitive selection among the loyalties. Congenial beliefs are absorbed, un-

congenial ones shunned, or more truly, fail to enter the orbit of consideration. The conventional combines with and may prevail above the emotional factor in the issue. The gregarious, the social, the cooperative forces draw upon the supporting emotions, and merge the two. Convictions are formed and sustained that are emotionally acceptable and traditionally accepted by a considerable group of one's tribes-folk, neighbors, fellow-citizens; these are institutionally reenforced by the sanction of tradition and authority. But with the systematization of knowledge and the expanding tutelage of science, the play of logical thinking increases notably. In any modern approach the psychology of conviction presents its problems as those of rational rivalry and logical selection, requires the investigation of the complex processes of inclination and plausibility, by which the few are chosen among the many called or calling. It asks why the corner-stone of one man's mental edifice is rejected by the builders of others.

To consider the process of conviction in any measure of detachment from its content is a sterile procedure. The life that is in them, however spiritually or formally sustained, flows in a definitely conditioned body. Lip-service in belief and hollow observance of custom is a common liability. The recital of creeds and rituals with a feeble sense of meaning finds its parallel in the allegiance to institutions, cults, laws, systems, parties, tenets, and practical attitudes with slight and vague appreciation of their basis, either by way of import or justification. For convention and the congeniality of adjustment rule. The part of reason, as likewise of a less explicit intelligence, in the maintenance of convictions that are none the less warmly cherished and embraced, is limited; these limitations form the clues to the understanding of the forces by which beliefs live and move and have their being. The recognizable features through which that being is made manifest appear as the points of attachment of belief; they determine *what* men believe as well as in another phase of their complex psychology they determine *why* men believe.

If this approach is rightly set, the chief determinants of the psychology of conviction, with bearing alike upon process and content, are emotion and convention. Fundamentally beliefs are formed and held because they satisfy, because they minister to some deep psychological craving, or some simpler need or indulgence; equally significant is the sharing of such beliefs with others, which is their indispensable social reenforcement and gives the added value of a conscious adjustment and an acknowledged approval.

Before considering at closer range the nature of the satisfactions that sustain convictions, their psychology should be brought into relation with yet more comprehensive, allied processes. The general formula is supplied by sensibility, which stands as the parent type of the instrument of distinction. As ever, the feeling factor is basic; the elemental distinction is that between pleasure and pain. Recognition promptly enters, and fuses as it extends the lessons of comfort and discomfort, of profit and loss. It widens rapidly to increasing circles of distinctive mental situations, inherent in the indirect responses required of complexly intelligent agents. Eventually distinction becomes an explicit and a logical process—a delineation between truth and error. In simpler situations men feel their way by support of sensibilities; gradually they come to reason their way through the problems that confront them. In any practical modern situation the rational factor is so pervasive, so intricate, alike by nature and tradition, that a prolonged and complex process of education is necessary to fit the individual to cope with it. The place of the keystone in the educative process is held by the structure of science, composed of highly specialized systems of relations, orderly analyses of causes and effects, rigid establishment of principles. These guide and support the most directive convictions of the human mind. In them appear the most adequate products of the logical mind, not detached from psychology but surmounting it. Yet the earlier modes of reaching convictions and the satisfactions attending them, persist; they yield but never with complete surrender to the later discipline.

The varieties of distinctions in the higher reaches of the mind, where lies the psychology of mature and complex convictions, comprise more than the logical ones. The regulations of attitude and action which they serve are commonly distinguished as of three orders: the logical, the moral, the esthetic. In all there is a rightness and a wrongness, a principle of selection which distinguishes alike the decisions and the natures of men. The logically right, the morally right, the aesthetically right is set apart—sharply it may be, with delicacy and uncertainty of distinction more commonly—from the wrong. More specific terms are available. Logically there is the correct and the false, truth and error; morally there is good and bad in conduct and intention; esthetically the standards are more variable, more responsive to condition, but the distinction between good taste and bad taste and their products is no less real. Convictions reflect these several phases of a common human nature.

Conduct is determined by logical, moral, and esthetic convictions. The factors cumulate and interact. The conviction is formulated as one, but embodies logical, moral and esthetic considerations. Now one and now another phase dominates; but the selecting mind is at once and compositely logical, moral and esthetic in its temper, expresses loyalty to each and all. Hence the complexity of the psychology of conviction. The same conclusion—which practically is a regulation of conduct through attitude and belief—is reenforced by logical, moral and esthetic supports. Men share a common allegiance in belief or action upon a somewhat different grouping of motives and reasons.

The practical criterion throughout is conduct. What men do depends upon what they believe, and how they feel; their thoughts and feelings are important because these affect their actions. The common utility is in the regulation of behavior. We thus return to the rôle of conviction as a determiner of conduct. Schooling and experience, book-learning and practical occupations, dealings with men and all manners of social observances and institutions—all of which are regulated by beliefs in the form of traditional explanations—leave as their deposit a logical sense, which acts after the manner of sensibility of the sensory type but with a more complex psychology. The logical sense also follows its type, reflects the stage of culture of the times, the social station, the mental development. It functions by accepting congenial orders of belief and rejecting others, while the very conditions of its acceptances preclude from its horizon orders of conviction beyond its ken. All this is familiar because the like holds of every evolutionary product. The logical sense is the slowest, most laborious, as well as the most precarious of psychological growths. As commonly exercised by the average man, it keeps him fairly safe from crude error so long as he remains on familiar ground. Within these limitations it distinguishes between the true and the false, much as his senses—in turn not so well protected as those of animals—distinguish (though not infallibly) between wholesome and unwholesome food. But to follow the lead of one's mind is a far more intricate matter than to follow one's eyes or one's nose. And similarly of one's moral sense and one's esthetic sense: these select among the alternatives of conduct and preferences of attitude, make their way through situations, and in their exercise according to one's schooling and tradition confer alike logical, moral and esthetic sensibilities and their satisfactions —all of them capable of indefinite expansion. The record of that expansion is in a profound sense the story of civilization.

The moral sense and the esthetic sense are truer to the parent type in that their affective ingredient is strong, and their social dependence marked. Moral convictions and the satisfactions which they bring—and with a different bearing the same is true of esthetic ones—affect the entire psychology of conviction. To neglect in any measure the moral and esthetic moments in the genesis and operation of convictions is to miss the genius of their nature, the source of their strength. Logical convictions and the satisfactions attaching to them are in all respects more derivative and more artificial, belong characteristically to later educational stages. Yet our chief concern is with them, because the latter-day issues which alone adequately illustrate the psychology of conviction as it affects our beliefs and attitudes, are so largely intellectual matters. Our approach to them and our faith in them is in the main a logical one. The disturbances of the even tenor of our logical ways by the strong currents of moral and esthetic emotions and sentiments form a vital part of our problems. They shape daily prejudices no less than the jealousies and unreasoning loyalties that precipitate world's crises.

The profitable pursuit of the psychology of conviction proceeds by the "case" method. Outgrown and discarded beliefs and attitudes, no less than those within our living experience, furnish the data for instructive analysis and suggestive diagnosis. Types of belief demonstrably false, yet once prevalent and commanding the allegiance of a considerable portion of men of fair or superior intelligence, still bring a valuable lesson in the analysis of the appeal which they once made, in the dissection of the motives and arguments which led to their acceptance. As such types of belief are selected from among modern, even contemporary movements, the use of latter-day enlightened criteria is the more justifiable; less allowance need be made for an imperfect logic and for the as yet unexplored regions of the continent of science. In point of fact the illustrations are continuous, with no breach of analogy between ancient credulity and its modern representatives, no abrupt change in the motives or the mechanisms of appeal. With due allowance for the change of outlook and attitude of other days and other ways, there must be considered the parallel changes in the grouping of forces at the focus of each problem considered. This gives the set to the psychology of the several "cases" of conviction; the cases fall into types, and the differentiation of types becomes the psychologist's task.

In clinical metaphor, each "case" requires the study of its

antecedents, of the mode of life, and the individuality of the patient and of the nature of the disease from which he suffers. Patient and disease are at once one and distinct. The study of a "case" of conviction requires knowledge of the antecedents of the problems and its bearings upon human interests, along with a study of the appeal which it makes and the psychology of its adherents. There is the psychology of the conviction as an objective belief, and the psychology of the convinced as a subjective issue. If one assumed a detached point of view, one might separate the strictly logical cases and recognize beliefs accepted upon evidence and applied coldly and consistently. In this view the logical plant—which is the human mind—would accept the crude material in the form of data and turn out the finished product as conclusions. If the result proves to be false, the fault lies in a too ready acceptance of premises or their imperfect manipulation. Such an analysis is bare and formal, literally true but psychologically barren. Yet, as will presently appear, a fair approximation to the type may be selected. The inclination to accept the premises upon the (inadequate) evidence, and the tendency to point the data to the ends reached (prepossession) are as real as the formal logical processes. These tendencies make the psychology of the problem, constitute its character.

"Cases" of this order may readily be summoned from the annals of science. Consider the explanation of fossils. Under a scholastic type of word-learning they were ascribed to a "stone-making force," "a lapidific juice," "seminal air," "tumultuous movement of terrestrial exhalations." To our type of science-drilled mind, all this is the mere husk and shell of explanation, empty verbiage, stale and unprofitable. Yet it is a factor in the psychology of conviction. Dogma and formulæ, formidable words, like popular slogans, help to carry conviction. They are more apt to contribute to obvious fallacy and pretense than to subtle error; but they play their part variably. On the other hand, when the upholders of scriptural literalism accounted for fossils as "sports of nature," as models made by the Creator before he had decided upon the most suitable forms for animals, or as snares hidden by the Almighty to tempt the unorthodox, we are plunged at once into definite prepossessions and allegiances to accepted doctrines which have powerfully affected not only the beliefs but the actions of men. Charges of heresy lurk in the background, and we enter upon the warfare of science[2] with dogmatically established conviction, how-

[2] It is in such service that Andrew D. White's "A History of the

ever fortified. When Voltaire argued (one does know how seriously) that "fossil fishes were the remains of fishes intended for food, but spoiled and thrown away by travellers; that the fossil shells were accidentally dropped by Crusaders and pilgrims returning from the Holy Land," we read the explanation with a strange sense of incongruity between data and conclusion. The true explanation might have appeared strained to Voltaire, because the facts underlying it were so completely out of his ken. Everywhere facts and theories cooperate and determine plausibility. We reach an undisputed "case" of credulity, not merely of weak hypothesis, when we learn of one Beringer who presented long arguments to prove that fossils were "stones of a peculiar sort, hidden by the Author of nature for his own pleasure." It is related that Beringer's students prepared baked-clay fossils of fish, flesh, and fowl—and even specimens with Hebrew and Syriac inscriptions upon them—and buried them in the Herr Professor's favorite digging places. Illustrations of these miraculous fossils were published, with the subsequent attempt of the author to suppress the work when the deception became known. As an individual "case" of credulity the incident would be amusing only; its significance lies in this: that not the inherent improbability of the conclusion by our standards, but the standard of judgment of the convinced scholar is the essential consideration. The tendency to accept the explanation of the origin of fossils (the theory) is congenial to the acceptance of the "finds" as corroborative (the facts). But in the "case" of fossils, however explained, an objective attitude is readily taken. The conviction carries no social or emotional consequences; one's views of fossils has no bearing upon conduct, or at best a most remote one. It sets up no allegiances of a practical order, creates no causes or loyalties, except as the convictions one espouses become extensions of one's personality, defended with the warmth of a cause embraced.

It is the peculiar merit of beliefs concerning our psychological nature, in contrast to the constitution of natural objects like fossils, that they carry such a wide appeal, play so largely among the motives that support vital convictions, while yet

Warfare of Science with Theology," 1896, has become a classic. Science is neutral in its campaign. It necessarily regards dogma as its enemy; it respects the province of religion when the latter refrains from an invasion of occupied territory. The tremendous struggle of the evolutionary position to gain a foothold in the nineteenth century is an adequate example of the varied prejudices which scientific argument may encounter in enlightened times.

patterned after the manner of scientific conclusions. An interesting group of beliefs relates to the interpretation of human types and differences. The ancient doctrine of temperaments, explaining the psychological types of men by the dominance of blood (sanguine), black bile (melancholic), yellow bile (choleric), and phlegm (phlegmatic), is as purely fictitious and as baseless as the cited views of the origin of fossils; but it persisted with remarkable tenacity and gave rise to a varied progeny of speculations that in turn dominated the convictions and the practises of men. The doctrine of the four temperaments was incorporated in the "humoral" system of medicine. From Hippocrates to Harvey, diseases were diagnosed and patients treated in terms of the "hot" and the "dry," the "cold" and the "moist," with most fantastic elaborations. Chills and fevers, parchings and perspirations, flushing and pallor, confirmed the findings; and the recovery of the patient—by the assistance of nature or in spite of the resistance to nature—proved the value of the system and established the prestige of the practitioner. The explanation of disease (theory) and the cure of ills (practise) form such a powerful motive to thought and action that the entire armament of the mind's powers—scientific and imaginative—was brought to bear upon the problem. The most ambitious of such constructions was the medical application of astrology, seeking the fate of men in the positions of the heavenly bodies. Medicines were concocted and administered with reference to the position of sun, moon and stars; elaborate correspondences were set up connecting the mineral, the vegetable, the animal kingdoms and the cosmic systems with the fates of men and the cure of ills that flesh is heir to. Disease is but part of man's fate. The prediction of the future, the control of fortune, the detection of talents—all combine and proceed upon the same flimsy logic and consoling psychology. The horoscope summarizes the issue astrologically as alchemy physiognomy, palmistry, phrenology and their like illustrate the persistence of the notions and the imaginative constructions by which they were satisfied. All these vagaries of the human mind in the realm of conviction—vagaries to us, but serious beliefs to former generations—embody a common psychological factor, that of finding what one seeks, which is vital to the understanding of each and all. Also central to their psychology is the tendency of the thought to shape the issue—the peculiar and elusive sense in which thinking aids and induces the result. In the treatment of diseases, this becomes "mind-cure"—the faith that facilitates

as well as the prejudice that blinds. The possession of this key to the situation—like the knowledge of the true nature of fossils—exposes the irrelevance and falsity of the several wild if shrewd guesses and proofs; but unlike the "case" of fossils, the motives contributory to convictions in regard to human nature and the control of human fate continue in subtle and complex form to shape current views, orthodox and unorthodox alike. We are still subject to disturbing influences in the psychology of our convictions, in the interpretation of our own psychology; the establishment of the logic of science in these realms is still imperfect by virtue of the same tendencies—admittedly far better disciplined—that gave currency to beliefs that seem to us preposterous in temper, absurd in evidence. Thus in retrospect the dual lesson bearing upon the psychology of conviction appears: first, that every advance in understanding is a step forward in logic, in the standards of evidence and the rigidity of conclusions, in the conceptions of plausibility and the discipline of the mind; second, that the forces inclining to belief persist, however altered their perspective, and continue to make the attainment of reasonable convictions and the consistent direction of conduct through them, a difficult and delicate task—the art of intellectual living. Wisdom is the name for the exercise of the logical function, with due recognition of the assets and liabilities of an ancient and fallible human psychology.

Such considerations make it pertinent to look upon persistences or revivals of beliefs continuing the older patterns of conviction, as survivals—never simple, often intricately disguised. Along with the older loyalties they incorporate the newer ones; particularly, they profess and in a measure maintain an adherence to high-grade logical standards. Their defection, however, is as commonly and as essentially a reversion to older psychological habits of belief as to a weakness in logical manipulation. Such "cases" of survival are most varied, indeed individual in composition. Interesting examples may be found in that wide domain already surveyed, belonging to psychology in a double sense: the one, is that the content of the belief relates to the conceptions of thinking and the views of our psychic nature; the other, is that the tendencies shaping belief in this realm are so characteristic of the "conviction" phase of our psychology. One of these "cases" and the most typical is the survival and revival of the belief in the possession of powers by some individuals in defiance or transcendence of the established laws and limitations of human endowment.

So characteristically psychological is this conviction that the phenomena associated with it have received the name of "psychical research"—a term irrelevant or misleading, but harmless if accepted as a convenient phrase. As here considered there is no choice but to consider the belief-tendency thus displayed as an inclination toward the supernatural. This merits detailed analysis; its "cases" are difficult, sometimes baffling. For the belief persists in minds thoroughly loyal to scientific ideals in other realms. The "cases" contribute a further factor to the psychology of conviction, and raise the interesting question of consistency. They suggest the existence of reserved areas of belief, more or less exempt from the limitations of logic, where the satisfactions of belief may be more freely sought and accepted without logical compunctions. Such indulgences are more appropriately considered under the personal phases of belief; but they contribute essentially to the convictions that keep alive the "proofs" of telepathy as of other modes of mental communication unrecognized by psychology, and the evidence of survival after death at the hands or mouths of mediums. The logical interest lies in the elaborate technique which such convictions have developed in support of the hypothesis, and the continued vitality of the belief despite repeated exposures of fraud in the accumulation of evidence, and woeful defects in logic in the arguments. Much of the belief in the supernatural is based upon the conviction that the facts cannot be otherwise explained, that deception is impossible. Such assumption in turn has its reasons; they lie in the will to believe and the gross underestimation of what can be done by deliberate or subconscious deception.

It is fortunate that "cases" of belief in the supernatural occasionally venture into the domain of the physical where their pretenses invite disclosure. Such detective service is in no way obligatory upon physicists and psychologists, even though their domain is intruded upon and their title challenged; it may be accepted as an obligation in the interests of social sanity which any competent protagonist of science may properly undertake. Such is the "case" of Paladino. Reduced to barest outline, in the presence of Eusapia Paladino—a Neapolitan woman of peasant status—tables moved, curtains blew to and fro, tambourines rattled, while seemingly her hands and feet were controlled. Incidentally the large compensations for witnessing the performance filled her purse. All this exploitation is commonplace and sordid. Upon the inability of men prominent in one or another scientific field to detect how it was done, is

reared the hypothesis that these occurrences demonstrate supernatural powers. When it is shown by counter-plotting, that the "medium" disengages one foot and lifts the table on her toes, the entire logical construction tumbles ignominiously; but the "psychology of conviction" of the case, like the moral, remains. The relation between premises and conclusion before the convincing disclosure, and the tendency to build upon them the belief in the supernatural, are just the same as before. The factors in the case are the enormous influence of the prestige of the sponsors for a performance that without it would attract slight attention; the weak logical sense that interprets the inability to detect how a thing is done as strengthening an otherwise unsupported hypothesis; but last as first, the tendency below the surface to accept the supernatural hypothesis is responsible for the "case."

This group of survivals, occupying the middle ground between old-time credulity and present-day controversies, is a fairly extensive one. It may be extended to include instances in which older conceptions are applied to newer problems with a weak sense of their incongruity. Such is the problem of animal intelligence. The inclination to ascribe to animals remarkable powers of mind is more creditable to human charity than to human thought; it is more a matter of sentiment than of logic. The science that speaks with authority on this issue is psychology; and we have already seen how difficult it has been for man to gain a critical knowledge of his own endowment and its workings, and the same holds of the minds of animals. Psychology has established how slow and laborious are the steps by which a decent logical control of data has been secured. The process is illustrated in the education of every child. Yet animal prodigies are placed on exhibition, and admiring audiences accept simple trick-performances as evidences of calculating horses, talking dogs, and educated animal geniuses. Learned books are written to prove that neither fraud nor self-deception has entered; the interest in the matter is so disturbing that commissions, on which professors of psychology serve, must be appointed to allay the mental unrest. Once more the discrepancy between performance and conviction is flagrant. A horse paws with his right fore-foot (as horses do), and is taught to continue to do so until he perceives a signal to stop. The performer advertises that the horse adds, subtracts, divides, extracts square-roots, counts, tells people's ages, knows grammatical construction, and what not. (It should be added that a bright horse or dog is so keenly observant that owners of such

animals may believe in the powers with the sincerity of self-deception.) The entire "case" would be ludicrous did it not furnish so neat an example of how conviction creates miracles, how readily prepossessions engender credulity, how inadequate is the popular notion of the foundation of mental processes which all enjoy, and how weak may be the logical sense that alone can protect against the acceptance of such performances at their alleged value. Even in the twentieth century the case of "mathematical horses" makes a distinct contribution to the psychology of conviction.

By this devious route we come to the present-day arena of contention in which opposing convictions, all professing a common loyalty to logical (or it may be to moral or esthetic) principles, defend opposite conclusions, favor antagonistic policies, bid for support as rivals, and array men in parties and factions, in schools and sects, as well as in hostile camps and campaigns. The controversial area of the psychology of conviction is a close neighbor to those considered; their boundaries touch and overlap. The older motives reappear with chastened mien; the analysis proceeds more considerately of subtle error and more delicate bias. Selection of "cases" is difficult by embarrassment of riches; for here lies the source of the saying: so many men, so many minds. The desire is to tap the controversial current at its richest flow, to illustrate the variety of its contributory streams, the many sources of its hidden springs. As a triad of such issues, sufficiently typical and distinct, may be selected the "case" of indulgence, the "case" of the feminine mind, the "case" of militarism and pacifism. In the one issue there stand embattled the prohibitionists and those who favor a sane, even an indulgent regulation of such practices (admittedly a serious evil in excess) as the use of tobacco and alcohol; in the next, the feminists contending for a nullification of the restrictions in the movements and careers of women, minimizing the differences of the sexes and their inherent consequences, as opposed to those who believe these differences to be vital, comprehensive and established; in the last the most intensely partisan arraignment by believers in peace of the horror, waste and unreason of war, by believers in war of the blindness, sentimentalism and visionary impracticality of pacifists. The fact which the psychology of "controversial" convictions faces is that in the presence of the same data and comparable schooling and environments, men reach deviating and opposite conclusions. Each party believes strongly that he has definitely proved his case. Yet it cannot be doubted that in the

main the minds thus in disagreement are fairly similar problem-solving instruments. They are not identical in nature nor mechanical in procedure. The human mind is by no means a loom receiving raw material, and with the pattern once set turning out a uniform product. For simple mathematical processes the formula holds; it makes no difference what mind performs the calculation. In controversial issues and practical policies it makes the greatest difference what manner of mind receives, elaborates, considers, and concludes. The individual factor dominates and yet holds true to type. Differences of opinion as of policy and taste are not chaotic or capricious or arbitrary. Despite all fluctuations, reason in well poised minds is an orderly procedure, and principles endure. The temptations to depart from such order are precisely the points of interest in the controversial phases of the psychology of conviction.

In explanation it is familiar that data known to one mind may be unknown to another, and that the importance attached to one group of data may differ in one mind and another. But behind all this and determining it is the predilection that selects and gives weight to groups of data of favorable bearing, inclines the interpretation to a predetermined bent, and reaches a conclusion more by reenforcement of an anticipation than by any progressive step; which means that it is not the force of evidence but the magnetism of conclusions that attracts. And this in turn is true because such specific predilections in regard to one issue or another are themselves the issue of a general perspective—compositely logical, moral, esthetic and practical—which determines the values of experience and arguments, that determine the set of one's convictions. We may call this character, we may call it a point of view or *Weltanschauung*, and bear in mind that this exists as really though in less finished and articulate form, for the unsophisticated as for the learned mind. Indeed one of the marked differences between them is the relative immunity of the disciplined mind to the disturbances of emotional predilection and subconscious prejudice. Yet the best schooled minds take their stand determinedly, with staunch convictions, claiming no exemption from human bias, but making allowance in their well-balanced judgments for the psychology of conviction as operative in themselves and in the world in which their influence makes itself felt. Any more intimate analysis requires the concreteness of a specific argument with all its ramifications and bearings, its traditional relations to custom and opinion. By considering the series of

steps by which one arrays one's self on one side or the other of such controversies as those concerning prohibition, feminism, and militarism, one will realize the manner in which facts, arguments, experience, predilection and one's general outlook upon the values and precepts of life, cooperate in the formation of positions, attitudes, loyalties—all of a practical order. In this estimate one must make large allowance for the persistent forces of convention, tradition, and imitation as individually operative; for these spread and fix conviction quite as they disseminate other habits of reaction; and parallel in importance remains the factor of a personal, emotional, temperamental congruity. Furthermore, in controversial questions where so commonly the data are imperfectly known and the arguments inadequately understood, convictions none the less proceed as confidently—possibly more confidently—under these limitations as in their absence. For doubt is an unpleasant state of mind, and the reaching of a decision and the taking of sides constitutes an indispensable type of satisfaction.[8]

We turn to the personal aspect of conviction, not as a novel factor (for everything is personal in the sense that there are no beliefs, only believers), but as a special emphasis. What men believe and why men believe converge in the satisfaction of belief—which is a personal reaction. The conviction once attained in conformity with one's psychology yields its satisfaction in the removal of doubt, the support of conduct, the consolation of faith, the guidance by principles, the consistency of a system or point of view, and adds to these the contented feeling of adjustment. Such are the common functions of creed, sect, party, principle, code, custom, loyalties. The act of subscription, allegiance, enlistment settles matters. Patriot-

[8] The incompleteness of this analysis of the psychology of controversy is obvious. It is intended only to prepare for the analysis of concrete cases; for the "case" method is the most instructive in this domain. Two possible factors are ignored: the one the element of intentional deception or the distortion of a biased interest; and the other the allied element of hypocrisy and inconsistency. These receive some attention under the consideration of the personal phases of belief; yet they play a specific part in controversial issues. In illustration the attitude toward education as a means of fitting the mind to play its proper part in life offers a pertinent example. The ordinary democratic view professes a cordial support of education and an admiration of the products of the trained mind. But actually it distrusts scholarship and deprives it of a reasonable share in social control. Such an attitude is one of suspicion masked by avowed confidence. It is an excellent and by no means isolated instance of the inconsistency between theory and practice, between profession and performance. Since most controversies have practical issues, this phase of the matter is often of decided consequence.

ism may be cited as a comprehensive expression of the issue and raises the question in how far one's patriotism is a sentiment or a conviction. An American can with difficulty conceive his allegiance of country as otherwise disposed. Yet he knows that millions of his fellow-citizens of like nature with himself profess an adopted allegiance, while a divided one (neglecting the complexities of the great war) is wholly compatible with a proper consistency of purpose and attitude. All this is fairly well understood, for it operates close to the surface of our deliberations, and our articulate sentiments. Following this trend, one might conclude that the desirable order of satisfaction is as obtainable from one type of belief as from another. Loyalty is everywhere similarly conditioned; the sense of attachment is the main thing and may be inculcated as readily upon the platform of absolute autocracy in government as of the freest democracy. It is not in such types of conviction that the distinctively personal factor is conspicuous; quite the contrary, it is in such larger loyalties—all supported by convictions—that the individual merges with the crowd, with the collective mass, and even surrenders to it. This, however, does not detract from the personal intensity of the convictions thus formed, nor from their efficiency. Upon the sentiment of patriotism, and the conviction that one's country is in the right, is based the integrity of nations, even to the supreme sacrifice of the soldier. Defection in this attitude may mean mutiny and treason. It is a sobering reflection that the ultimate bond of nations, as everywhere the unity of a collective purpose, rests upon the integrity of the personal convictions of those enlisted. This is the fundamental reality and gives to the study of conviction its unique importance. That such personal intensity of conviction may come from any or many sources, must ever be borne in mind.

It is in the more individual affiliations and in the narrower circle of one's loyalties that the personal element appears in stronger relief. There is one system of psychology, with bearings upon the genesis and nature of conviction, that is entitled to precedence in our considerations. The psychology of Freud is reared upon the relation between motive and belief, upon the wish as father to the thought. In broader outline the Freudian system explores among the subterranean roots of motives to discover the promptings of thought and action. It emphasizes the subconscious; and it builds upon a group of mechanisms, by which the apparent, superficial stream of thinking is brought in relation with the deeper, hidden sources of its flow. To no

mental product does the system apply more intimately than to convictions.[4] For the first and last things in the Freudian psychology are motives; and the clue to conviction (beyond the realm of undisputed reason) is motive. In the view of Freud the mental life is a struggle—a conflict between what is, what we are and must do, and how we should like to have things, what we should like to be and do. So imagination enters to bridge the gap, and the fictitious pleasures of day-dreaming and of conclusions not untouched by delusion yield their satisfactions. Truly rationalization enters, and we justify our beliefs and acts by reasonings to conceal their real motives in emotion and desire. The mechanisms of thought are mechanisms of concealment—a psychological *camouflage;* reason masks emotion, in that the acknowledgment of the emotion is unpleasant or otherwise tabooed, while the appeal to reason is accredited and creditable. The masking devices are varied, some dramatic, others shrewd, others subtle. The most typical is the device of compensation. Lacking one satisfaction we minimize its loss by setting up another in its place. A salient example is that of a man of checkered and uncertain career, in all essential respects a failure in life, despite conspicuous talents, who in announcing the subject of his personal reminiscences as a platform topic chose the title: "How I Achieved Success." That title is a Freudian confession of failure, disguised to the self that makes it. Similarly, if the German mind is prepared to stand by its Austrian (Freudian) ally in the psychological field, the Teutonic insistence upon the superiority of German "Kultur" is to be interpreted as a Freudian confession of a sense of lack, the inability to achieve that delicate appreciation of the values of life that is characteristic of the French, or the well poised directive capacity and clean-cut analysis of the English mind. The compensation is the gigantic and immodest delusion of superiority. Suspicion or accusation is often of the same nature, imputing to others motives present in oneself, but disowned. The same applies to apology in that it implies a self-accusation: *qui s'excuse s'accuse.* The conception of convictions as formed or supported by this mech-

[4] The parallel applications of equal importance are to the free material of dreams, reveries, imaginative excursions (also to seemingly accidental lapses, like forgetting and mislaying) and to impulsive, aberrant conduct. All these orders of expression lose their detached character when supplied with the clue of motive. It is not necessary to accept the extreme Freudian interpretation, particularly the reference of all these mental products to the motives of sex. The Freudian view is entitled to respectful consideration; it has proved suggestive in many directions.

anism of emotional transfer—in consolation or compensation—yields a restricted but authentic application of the Freudian principles. The Freudian mechanisms apply more fully to expressions of stronger, more original emotional tone—like the instinct of motherhood lacking its authentic outlet and seeking substitutes in the mothering of pets or causes; yet like these, convictions serve as a temperamental satisfaction by employment of similar devices. Other common Freudian factors may be noted. There is over-determination, overdoing—in excess of recoil, through some internal resistance or scruple, swinging far to the opposite extreme. The characteristically Freudian aspect of the issue is that the impulse to the extreme is felt, but the motive source remains subconscious; yet it operates and projects from its depths a sense of trouble and difficulty. Conviction may be held waveringly yet longingly, shiftingly in successive devotion to fads and "isms."

The "conviction" aspect of the conflict is a struggle for consistency as well as for contentment, which in its ripeness aims at the harmony of one's beliefs and conduct. Such a consistent whole is a personality, many sided but single minded. Thus in tracing the orbit of conviction, we constantly return to the emotional motive—an emotion close to will. The common name for this is desire, the Freudian *wish*. In so far as the Freudian diagnosis applies, it is the unfulfilled wish, the thwarted desire that shapes the true motive of conviction; it operates in so far as the belief is by nature or adoption warmly cherished, with a deep personal absorption; it is peculiarly applicable to extremé semi-pathological temperaments, in which the processes are emotionally intensified. But a more common Freudian mechanism peculiarly applicable to the genesis and support of convictions is rationalization, which is the justification of belief to reason. We actually believe by virtue of a trend anchored in personal desire, and have recourse to reason to mask this source—to clothe a personal conviction in more presentable garb. Accepting the motive as a "reason," we believe for one reason and defend conviction for another; such is the Freudian defensive and self-deceptive mechanism. In some measure the conviction may be unreasonable, yet it secures and maintains its hold by conformity to authentic psychological processes.

The mechanisms thus described in Freudian manner have been otherwise and previously recognized; the Freudian setting adds to their illumination and to their relation to our general psychology. In application to conviction, we must proceed

more delicately, with discerning allowance for the type of conviction involved. We recognize that we are committed to a certain pride in our rationality; we make claim to be reasonable beings; and for this end our dress-parade selves argue and defend as well as ignore and conceal. By quite the same route in practical matters, we admit that our interests come to determine our positions; and yet know that scientific judgments must be disinterested and unprejudiced.

Intense conviction obscures vision; yet enthusiastic interest opens our eyes; we must accept the liabilities along with the assets of our own psychology. In Freudian aspect beliefs avoid contact with reality by surrounding themselves with a defensive smoke-cloud of security; in scientific employment, hypothesis and speculations extend the study of reality, alike in detail and in scope. Neither the one nor the other issue is necessarily involved nor readily avoided. In consequence the consistency of the varied convictions of all sorts and conditions of men on all sorts and conditions of questions is a partial one. An equal consistency in all one's varied interests is an attainable but rare ideal, possibly not even a desirable one. A common form of inconsistency suggests the hypotheses of reserved areas of conviction in which predilection may disport itself in freedom from the restraints of too rigid a logic. It is possible that a man of science may be cautious and logical in his special domain, but in matters outside of it in which a personal bias enters, may be uncritical, even credulous, and accept or propose arguments fallacious or weak. Such defection constitutes the personal factor in the prevalence of the "survival" types of conviction already reviewed. The hypotheses of "reserved areas of belief" applies characteristically to the spiritualistic phase of "psychical research"—that is the acceptance of evidence of the communication by the departed through mediums; it applies particularly to the "case" of Paladino, while yet this "case" is made by the prestige attaching to the scientific reputation of her sponsors. The hypothesis applies sporadically through the several incidents that have attended the renaissance of spiritualism since 1850. Inclination to accept the spiritualistic belief is the main factor; the evidence plays a secondary part. Those responsible for such evidence contribute to the psychology of deception,[5] as the deceived contribute to the psychology

[5] I have considered these problems in an earlier volume: "Fact and Fable in Psychology" (1900), particularly the first five studies. Accordingly the types of belief in which credulity, intentional deception, and weakness of logical sense play the leading parts in the dissemination of

of credulity. This holds for the vast majority of believers; but for the few and the leaders of the movement, the conviction suggests the operation of a reserved area of belief. Whether the reservation is due to a Freudian complex is an individual question.

There is a further aspect of such allegiances: namely, the attraction which a belief excites by its very departure from rationality; the tendency is due to the lure of the obscure. Its most philosophic expression is mysticism. But the cooperation of other factors is apparent. Such occult and irregular beliefs grow by contagion; they grow by prestige; they grow by a congenial selection of adherents; and a factor in the last contribution is the satisfaction of clinging to the esoteric, of belonging to a different order, a less conventional cult than that which secures the adherence of the ordinary man. Even radicalism makes its converts by some measure of such appeal. But simple credulity, or logical weakness is never absent, and constitutes a personal factor in the issue. Consider such a belief as that in phrenology, which is fairly modern and continues with revivals to recent times. What the attraction of such a belief may once have been or how it continues to exist, albeit with lowered caste, it is not easy to determine. Lack of scientific training may be the chief factor in its spread; but each such belief leaves the problem of how this particular belief selects its recruits. The same is true of homeopathy. In both cases those who follow the system may have difficulty in describing either the basis of the principles, or their own adherence to them. Such excursions into the history of personal attachments might add to the psychology of conviction; but their pursuit leaves the central problem of the present study. Obviously such beliefs linger with a low vitality, and the change of their clientele suggests the degeneration of a city neighborhood when a residential district loses its prestige.

Continuing in the direction of the irregular, we come to beliefs that may properly be called pathological. Such beliefs are so strikingly individual that they are ordinarily not shared by others. They are called delusions and are characteristic of insanity in its various forms. Here the personal factor reaches its maximum scope. Such delusions may likewise appear as Freudian compensations; their modes of rationalization are so irregular that therein is recognized the mental aberration which

false beliefs, are not emphasized in the present consideration. The portions of the volume just referred to may be accepted as an amplification of this position, in terms of analysis and illustration.

represents the extreme issue of personal conviction in its deviation from logical standards. The manner of reaching one's convictions as well as the convictions reached thus become a criterion of one's sanity. Such (delusional) beliefs do not affect others; nor are they taken seriously. The rare "case" in which an individual belief of this type plays a part in a system of wide acceptance in modern times is supplied by the case of Mrs. Eddy. Her personal delusion of a "malicious animal magnetism" runs through "Christian Science" so far as that system reflects her life-history. She accused disciples who had escaped from her influence, of this peculiar form of sorcery (mental poisoning, she called it), and took all sorts of precautions to avoid its dire effect. Naturally the great mass of her followers ignored this strange belief; yet their attitude to the tenets promulgated by Mother Eddy, if consistent, implies a subscription to this belief also. The inclusion of Mrs. Eddy's belief in malicious animal magnetism is accordingly pertinent to the personal and pathological aspects of conviction.

The practical issue of the operation of these several cooperating and conflicting factors is the tolerance of all manners of convictions and compromises and makeshifts in the mental household. No one is completely logical, and no one is devoid of the logical impulse and a certain logical consistency. But the psychological trend runs more deeply, more pervasively. Conviction appears as a compromise of logic with psychology. The solution of our problems depends not alone on the discovery of truth, but on the control of the means of securing its acceptance. To gain for beliefs their proper recognition amid the rivalry of convictions and of the forces sustaining them, is an art. The slowness and laboriousness of human progress is a direct consequence of these conditions and limitations of the human mind. The acceptance of new truth meets with all sorts of oppositions and resistances, which though collectively expressed are individually experienced. The conflicts of men, as of nations, take place in the arena of personal conviction. Purposes, policies, jealousies, ambitions, sentiments converge in the formulation of a conviction, which may be as simple as a slogan and as complex as a destiny.

Viewed retrospectively, the greatest triumph of the human mind was the gradual removal of large areas of belief from the influence of the psychology of conviction. Scientifically established truth came to proceed objectively, undisturbed by interest in the outcome of inquiry and determined by the sanction of verification. The disestablishment of the anthropocen-

tric view of the universe culminated in the removal of human desire from its place of dominion in the formation of belief. The process is but partially accomplished even in disciplined minds, and for the great masses of men plays a subordinate part in the scheme of their lives. Moreover, the existence of so many controversial issues, in which conclusions are far from clear and yet action is demanded by condition, imposes the exercise of judgment upon mixed motives of logical loyalty and psychological appeal. For all these reasons the understanding of the stream of influences that play upon the genesis and shift of conviction is a permanent occupation of the psychologist. The obligation to seek control of human convictions through a study of their nature applies with peculiar force to twentieth-century conditions in which a sentiment of democracy prevails; for democracy imposes or encourages the consideration of convictions by inviting adherence to parties and confirming the verdict of the ballot. Democratic forces operate far beyond the political realm; there is hardly a page of the daily press that does not make an appeal to men's actions by prevailing upon their convictions. Rival newspapers bring to their selected clientele the reenforcement of convictions already espoused. Towering above all other issues are the set of convictions that have arrayed the dominant nations of the world in a colossal life-and-death-struggle. The world-war is a war of convictions, tragically consigned to the ordeal of a scientific armament of destruction; and the decision, however reached, will establish one set of convictions in the minds of men, and depose its rivals. Once the normal relations of men and nations again prevail, we shall be able to look back upon the struggle with the saner logic of a scientific judgment. While the awful struggle continues and in its progressive steps, we become the passionately interested witnesses of the play of psychological forces on the largest scale that has ever been enacted. Parallel with the clash of armament is the process of conviction; both will participate, and presumably the latter with greater influence, in the negotiations of peace—in the restoration of a normal outlook upon the values of life and their control by sane convictions.

REPTILES AS FOOD

By PROFESSOR A. M. REESE

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IN these days when "conservation" is a byword and every man, woman and child is, or ought to be, thinking of the food problem, it may be of interest to notice the extent to which the comparatively small class of animals, the reptiles, are used as food, and to call attention to one or two ways in which they might be more extensively used.

For the sake of convenience, the class will be divided into the four old orders: the Chelonia, or turtles and terrapins; the Lacertilia, or lizards; the Ophidia, or serpents; and the Crocomilia, or crocodiles and alligators. Of these the first is the most important and will be first discussed.

Turtles are used for food over practically the entire world, but it is said their flesh is forbidden to Mohammedans, and is abhorred by certain Greeks.

Nearly, if not all, species may be eaten, but there is, of course, much difference in the quality of the flesh, and Surface states that during a strike of miners in eastern Pennsylvania many of them were made sick by eating turtles, supposedly the box tortoise, so that the common idea that this form is inedible, at least at certain seasons, is probably correct. There are also a few species whose offensive odor makes them undesirable as food. It is said that even the flesh of the green turtle, about to be described, is poisonous at certain seasons of the year in some countries where it is found.

THE GREEN TURTLE, *Chelone mydas*

This is, perhaps, the most important of the turtles as an article of food; it is an important article of commerce, and is an important part of the diet of some of the tropical peoples. It is found in tropical and semi-tropical seas throughout the world, and may reach a weight of five hundred pounds, though these huge ones, are not so good for food; those found in markets usually weigh from fifty to seventy-five pounds, and sell for about 35 cents per pound. The name has been given because of the green color of the flesh. Jamaica was formerly

and perhaps still is, one of the chief centers for the green turtle industry; Key West has also been an important center. In one year fifteen thousand animals were received into England, besides a large amount of dried meat in cans, the meat for canning being cut into strips and dried in the sun, where it acquires almost the consistency of glue and requires long soaking in water before it is fit for food. As in many other turtles, the oil may be extracted and used for culinary purposes in place of butter or olive oil.

In markets these turtles are kept lying on their backs not only to keep them from escaping, but because, being adapted to life in the water, they would not be able to breathe if laid upon a hard surface, right side up; their plastron is not firm like that of a land form, and the weight of the animal when not supported by the surrounding water so compresses the internal organs that suffocation is produced. The flesh may be cooked in various ways and is said to be very digestible.

The green turtle lays from two hundred to three hundred leathery-shelled eggs that are said to be more nutritious than hen's eggs; a dozen of them may be eaten at once. The eggs, which are carefully buried and concealed by the female, are found by prodding in the sand, along the shore, with a sharp stick.

Along the Amazon and Orinoco rivers the eggs of various turtles form a very important article of food; they are preserved by rolling and packing in salt, and in other ways. A kind of oil, much esteemed by the natives, is made from them, preserved in jars, and used like butter. The collection of such enormous numbers of eggs has nearly exterminated the apparently limitless numbers of turtles in some places.

The eggs of many of our common fresh-water turtles are good as food if taken from the animal or obtained soon enough after being laid.

THE LOGGERHEAD TURTLE, *Thalassochelys caretta*

This is another large, marine form, somewhat similar to the preceding, that is sometimes found in the markets, though it is of much less value.

THE DIAMOND-BACK TERRAPIN, *Malacoclemmys palustris*

This species is supposed to be the most delectable of all the turtles. It is a comparatively small animal, rarely reaching a length of ten inches, that is found in the salt marshes of our coast, from Massachusetts to Texas, those of Chesapeake Bay being, perhaps, the most famous. It has been named because

of the angular areas made by the concentric lines on the carapace.

They hibernate by burying themselves in the mud along the shore, whence they are tracked and dug out for sale in the markets. Their rarity and comparatively small size, combined with their unusual flavor, cause these turtles to be among the most expensive of our food products. A single animal of seven inches' length is worth about six dollars, and the price increases at the rate of about one dollar for each additional half inch in length; a seven-inch specimen weighs about four pounds. At such prices it would seem highly profitable to raise these turtles under artificial conditions. The experiment has been and is still being tried, but the slow growth of the animals and the small number of eggs produced each year make the enterprise a doubtful one from a financial point of view.

THE COMMON SNAPPING TURTLE, *Ghelydra serpentina*

This familiar chelonian inhabits ponds and slow-running streams of the United States east of the Rockies. It sometimes weighs as much as forty pounds and is named from its habit of snapping at any annoying object with such vigor that a human finger may be amputated by a moderate-sized specimen. They are sold in large numbers in some of the greater cities and bring about ten cents a pound.

The food of the snapper consists of all sorts of animal matter, and it is sometimes very destructive to ducks and other water fowl, destroying entire broods of the young birds. Should the snapper become a pest in the duck pond, it may be caught, according to Surface, by baiting a strong fish-hook with a piece of tainted meat and tying the line to a slender stake or tree that will bend when the turtle pulls. The hook must be fastened to the line by a length of slender wire, so that the turtle can not bite off the hook and escape.

In its feeding habits, then, it is probable that the snapper is more harmful than beneficial; the birds, frogs and fish it destroys more than making up for the insects and other pests that it eats.

THE SOFT-SHELLED TURTLES, *Genus Trionyx*

There are several species of soft-shelled turtles in the United States, and, while they are differently named by different writers, they may all be recognized by the soft, leathery character of the shell and by the proboscis-like snout. They are thought by some to be the most palatable of all our turtles

with the exception of the diamond-back, and, as a large specimen may reach a length of eighteen inches, they furnish, in some sections, quite a valuable supply of food.

Their omnivorous habits make it difficult to determine their economic importance in this regard. It is said they are very destructive to fish and water-fowl in some regions; on the other hand, they may do an important work as scavengers and as destroyers of insects. Many of them are savage in disposition and their jaws are capable of inflicting ugly wounds. Most of them are strictly aquatic in habits, being found in ponds and muddy streams, which they seldom leave.

The fresh-water turtles that are used for food or for scientific purposes are captured in various ways. Many of them are taken, sometimes scores in a day, by digging them out of the mud or sand in the bottom or along the shores of the ponds or streams in which they live. At the approach of winter they bury themselves in these places and hibernate until spring. With a pointed and barbed rod the hunter prods into the mud and on feeling a turtle pulls it up with the rod. Turtles are also caught on a line baited with meat, as mentioned above. In the case of the soft-shelled turtle the meat is kept near the surface by a cork. Wire traps, with funnel-shaped entrances like fish traps, are often used and are baited with ears of corn that become sour and attract the turtles. Such traps must be examined at moderately frequent intervals or the turtles may drown. The collection of fresh-water turtles, in some sections, is quite an important industry.

The lizards are important to mankind chiefly as destroyers of insects, but a few of them are used as food in tropical and semi-tropical lands. Of these the giant Iguanas, reaching a length of six feet or more, are the most important. The flesh of these lizards is said to be of a delicious flavor, resembling chicken. In the Bahamas the lizards were formerly one of the most important articles of food; they were hunted with dogs, and kept in captivity until wanted. They have been hunted almost to the point of extermination, in some localities. The way in which the early Spaniards overcame their repugnance to these ugly reptiles is told by Peter Martyn thus: "These serpentes are lyke unto crocodiles, saving in bygness; they call them guanas. Unto that day none of oure men durste adventure to taste them, by reason of theyre horrible deformitie and lothesomnes. Yet the Adlantado being entysed by the pleasantnes of the king's sister Anacaona, determined to taste the serpentes. But when he felte the flesh thereof to be so delycate

to his tongue, set to amayne without al fear. The which theyse companions perceiving, were not behynde hym in greedynesse; insomuche that they had now none other talke than of the sweetnesse of these serpentes, which they affirm to be of more pleasantt taste than eyther our phesantes or partriches."

The eggs of the larger lizards are also used as food in some countries.

Though snakes are esteemed as food in many lands, it is not likely that they will ever be an important article of diet in this country, both because of the almost universal repugnance with which they are regarded and because of the comparative scarcity of large serpents within our borders. Our larger black snakes, though reaching a considerable length, are so slender that the amount of flesh in their bodies is not great, and there is probably hardly one person in ten thousand who would knowingly eat a snake.

With the crocodilia the matter of size cannot be raised as an objection, since the largest members of this order may reach a length of thirty feet and a weight of many hundreds of pounds. Of course, neither an alligator nor a crocodile is a very attractive looking animal, but when skinned and dismembered the body looks no more repulsive than any other carcass that may be seen in any butcher's shop, and the flesh is as white and attractive-looking as the best beef or pork. The eggs of the crocodilia, which are usually about as large as those of a goose, are often eaten by the natives of the tropics. Never having eaten an alligator *egg,* I can not speak from personal experience of its flavor; but it has always seemed strange to me that more use is not made of the flesh of the alligator. This flesh is often said to have too strong a flavor to be palatable; I have eaten it, and it had no such rank taste, but was decidedly agreeable, being, as might perhaps be expected of so amphibious an animal, somewhat like both fish and flesh, yet not exactly like either. Perhaps greater care should be taken in skinning an animal that is to be used for food in order that the flesh be not tainted with the musk. It may be a lack of care in preparation that has given rise to the impression that alligator meat is too strong to be pleasant. It is perhaps, also, the "idea" of eating a reptile that makes the meat unpopular. A half-grown boy, who was once in the swamps with me, had expressed a great aversion to alligator meat, so the guide, one day, offered him a nicely fried piece of alligator meat, saying it was fish; the meat was eaten with evident relish and the diner was not told until after a second piece had disappeared what he had been eating.

It always seemed strange to me that the poor people of the south should not more often vary the monotony of fat pork and corn bread with alligator steaks. Whether the meat could be smoked, or salted or canned so that it would keep in a hot climate I do not know; I am not aware of any experiments along this line. But it would seem as though it could at least be canned as well as any other kind of meat.

Another point that would have to be determined is whether the flesh of the crocodilia of Central and South America is as pleasant to eat as that of the Florida alligator noted above, because the latter animal has been so persistently hunted by sportsmen and hide hunters that its members have been greatly reduced, in fact, almost to the verge of extinction in many regions. In many parts of tropical America the various species of crocodiles and caymans are said to be very abundant, so that if a means could be devised to preserve the flesh near the place where the animals are killed, a large supply of meat might be obtained. At the same time, the hides, though not of such good quality as the Florida skins, might be of considerable value in these times of scarce leather.

It is probable that, on account of the general prejudice against eating reptiles, it would be necessary to give the commercial product some trade name, such as is being used to induce the finicky American public to eat certain sharks and other perfectly good sea fishes. The selection of such a name would be an easy matter, and if the canned "Yacare," as the flesh of the cayman is called in South America, should prove as palatable as the freshly fried alligator steak, it would have a ready sale.

We Americans have a lot of silly ideas about what is fit for food and what is not, and it is time that we got rid of some of them.

ENTOMOLOGICAL RESEARCH AND UTILITY

By DR. E. P. FELT

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THERE has been no period when there was more demand for practical means for the control of insects—methods which could be applied in the garden, the field and even forests and yield results commensurate with the costs. The reason is found in the high prices of all crops and the urgent need of greater production. The latter may be secured by increased planting or better protection and usually by a combination of the two, since a greater acreage is easily offset by insect depredations or other untoward developments. It is only necessary to recall that estimates made several years ago of the total annual losses caused by insects in the United States overran the billion-dollar mark and to-day probably approach twice that sum. This gives an idea of what insect activities mean in a practical way. A large proportion of this waste is preventable and if it were eliminated would go far to relieve the burden of taxation.

All manner of crops, animals and products are levied upon by insects. Wheat may be blasted by the Hessian fly, green aphis and wheat midge; potatoes seriously damaged by potato beetles, wire worms and white grubs; corn destroyed by white grubs, corn root worms or army worms; cotton has its enemies in the cotton boll weevil and the cotton worm; stored food products may become infested by meal worms, contaminated by roaches and spoiled by weevils; fabrics are ruined by clothes moths; lumber and even dwellings are rendered worthless by various borers, while our domestic animals are worried by horn flies and driven to desperation by black flies and gadflies. Man is by no means exempt from attack by malevolent forms such as body lice, especially in the trenches; the house fly with its disease-carrying potentiality is a menace in both home and camp, and the same is true of a number of mosquitoes. This has all become increasingly important under present conditions, especially in the field and camp, where opportunities for protection are greatly reduced and the chances for infestation increased on account of the frequent changes and enforced associations.

In other words, the menace of the insect has become immensely greater and with changing conditions incident to war, especially in those unfortunate sections blighted by military activities, there will be new adaptations on the part of the more

destructive insects. The lower type of agriculture due to the lack of labor and the absence of sufficient fertilizers is apt to be followed by insect injury of a type now largely restricted to less progressive regions. The grasshopper, that plague of ancients and devastator of the western plains, especially in earlier days, may find among the scanty crops of poorly cultivated fields conditions favorable to extended depredations. This period of readjustment is the time when most careful attention should be given to insect life and the causes favoring its development. There is a special need for searching out ways of preventing loss by modifications in practise, since many of the remedial operations such as spraying may be made impossible owing to a lack of labor and an absence of means. There is no extra expense, for example, in delaying the sowing of wheat until danger of attack by the Hessian fly has passed. It costs practically nothing to modify crop rotations so that corn and potatoes will not be planted on sod land badly infested by white grubs or wire worms, thus inviting disaster. Such matters are of great importance in times of stress. We should know that the successful prevention of injury in any such manner must depend upon an exact knowledge of habits and limitations, something which can be acquired only by years of experience or through painstaking investigations.

Introduced and new insect pests also present serious and in some cases acute problems which may demand immediate solution if extended depredations are to be avoided. It is well known, for example, that over half of our most injurious insects have been introduced from abroad, and during recent years there have been formidable additions to the number, such as the gypsy moth, the brown tail moth, the pear thrips and the cotton-boll weevil, to mention only a few. This process is continuing and no one can foresee its limits. The past season has witnessed the discovery in New York state of an apple and thorn skeletonizer, a European insect capable of defoliating entire orchards and one which appears to have become recently established in this country. Native species are responding to changed environment and causing losses which can not be prevented without the direction possible through exact knowledge of the life history and habits of the pest. Both the introduced species and native insects which become seriously injurious give little warning of their destructive abilities and frequently arise from the ranks of the previously unknown or almost ignored. This class of pests alone justifies long continued studies in unraveling the numerous biological problems presented by insect life, since no one could foretell what facts, though apparently insignificant of themselves, may determine

the possibility of practical control for widespread and destructive pests.

The assembling on fields of battle of representatives from all parts of the world, and the inevitable later scattering of units means the establishment in many localities of individuals infected with most of the diseases to which man is heir, and with a presumptive relaxation of the present rigid military control upon the establishment of peace, there will be an unexampled opportunity for various insects to serve as carriers of deadly infections so frequently associated with war, such as typhus, bubonic plague, cholera, typhoid fever, dysentery and smallpox, most of which may be carried by insects even if they are not largely disseminated in this manner. Only the most thorough precautions can prevent extensive outbreaks of these diseases, and certain safeguards are possible only when there is an intimate knowledge of the habits of the insects serving as carriers. The warstricken areas lack the ordinary sanitary provisions, and the numerous cases of noxious diseases occurring therein can not but serve as centers for the dissemination of infection among an unusually susceptible population due to the lowered vitality incident to exposure and deficient nutrition. This is the situation obtaining in some sections of the world and very likely to spread over considerable areas unless the danger is fully appreciated and every possible precaution adopted.

Practical insect control depends absolutely, whether it be recognized or not, upon exact knowledge of the life history and habits of insects. Outbreaks by various pests are simply responses to environments and it is the duty of the scientist to read carefully the pages of history and determine so far as practical what portions are to be repeated in the near future. Changes in agricultural methods are inevitable with the scarcity of help, and we must see to it that such modifications do not produce unduly favorable conditions for insect outbreaks. We must anticipate unexpected mischief so far as practical, and this for the entomologist is no small undertaking when the enormous number of species he is called upon to deal with is taken into account. This is no time to restrict research. There should rather be a great extension of activities if the entomologist is to render the best service to his country and to mankind. He should seek as never before for the limiting factors which render an insect innocuous and if possible prevent it becoming unduly abundant and destructive. This should be a campaign of knowledge directed largely toward preventive measures, since combative and remedial measures may frequently be impossible.

POTHOLES: THEIR VARIETY, ORIGIN AND SIGNIFICANCE[1]

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INTRODUCTORY—OCCURRENCE AND TERMS USED

WHERE streams have eroded channels in bed rock, hollows of characteristic shape, called "potholes," commonly appear. In ground plan potholes are typically circular or elliptical, but often deviate from this ideal shape. As a general rule such depressions are of less diameter at the top than in their middle sections or bottoms.

The term "pothole" has at various times been criticized by geologists, notably by Hershey[2] on the ground that the word "is inelegant and grates harshly on people of sensitive temperament." He suggested the use of the term "remolino," a Spanish word used in the Republic of Colombia for such hollows. Hershey's proposal elicited several comments for and against the use of this term. Farrington[3] favored the substitution, because, according to his idea, "remolino" suggested more adequately than "pothole" the manner of formation of the holes. Hilder,[4] on the other hand, pointed out that the Spanish word has several meanings, for example, "a whirlpool" or "whirlwind," and that it had even been applied to a turbulent mob of people.

In geological literature there are many articles describing "giants' kettles." These papers refer almost exclusively to that type of pothole development due to the work of glacial waters. There seems to be a paucity of articles dealing with

[1] To Prof. O. D. von Engeln, at whose suggestion this investigation was begun, the writer is indebted for friendly advice and interest shown during the progress of the investigation.

The writer greatly appreciates the kindness of Mr. G. H. Hudson of Plattsburg, N. Y., and Mr. G. F. Morgan, of Ithaca, N. Y., in supplying and permitting the use of several of their photographs.

[2] Hershey, O. H., "Pothole vs. Remolino," *Science*, N. S., Vol. X., p. 58, 1899.

[3] Farrington, O. C., "Pothole vs. Remolino," *Science*, N. S., Vol. X., p. 187, 1899.

[4] Hilder, F. F., "Pothole vs. Remolino," *Science*, N. S., Vol. X., p. 88, 1899.

potholes that have been sculptured by existing streams or that are now in process of development along such stream courses.

The primary purpose of this paper is, therefore, to describe and account for the existence of pothole hollows in the channels of existing stream courses, giving especial attention to observation of such phenomena as they occur in horizontally bedded strata composed of shales and sandstones.

Since, however, potholes have always excited considerable popular interest and as such phenomena are by no means all of the normal type to which the principal discussion refers, a review of some of the earlier literature on the origin of such depressions, together with an attempt to classify and briefly describe the several variant types, will serve to give the reader an appreciation of the broader aspects of the subject.

Early Ideas concerning Potholes

In the earlier literature, generally with reference to occurrences in glaciated regions, the terms, "giants' kettles," "giants' caldrons," "Indian kettles," "Indian mortars" and "wells," were often applied to potholes; indicating that their origin was either superstitiously ascribed to the work of giants, primarily because of their large size, or referred to the handicraft of the North American aborigines. Brögger and Reusch[5] cite several examples from Norway of fanciful notions regarding the origin of such hollows. In one instance where a large pothole excavation had been cut through by a road, the belief is that "there St. Olaf turned his horse round" and in other instances from the same region the idea prevailed, that, since occasionally the holes resemble in outline the print of a human foot, they are footprints left by giants while taking huge strides across the country. On the west coast of Norway the term "*gygre-serrer*," or "giants' chairs" is used in referring to potholes. Again, according to Brögger and Reusch,[6] one of the early writers, Neels Herzberg, had both strange and rational ideas concerning the hollows. He suggested that they were due to the power of lightning, or to the activities of a monster sea worm, of which he thought examples were perhaps still to be found in the deep, such animals having "worked them out in olden times, before the rock had hardened, just as boring mussels do in our day in a small way." Herzberg thought it

[5] Brögger, W. C., and Reusch, H. H., "Giants' Kettles at Christiania," *Quart. Jour. Geol. Soc. of London*, Vol. 30, p. 750, 1874.

[6] Brögger, W. C., and Reusch, H. H., "Giants' Kettles at Christiania," *Quart. Jour. Geol. Soc. of London*, Vol. 30, p. 762, 1874.

not impossible that potholes might be formed by ordinary raindrops during the lapse of a tremendous period of time, in the same manner that he had seen a miniature kettle hollowed out by twenty-two years' continual dropping of water on a flagstone outside his window. Although Herzberg entertained such varied ideas of pothole origin he also seems to have hit upon the true explanation of the normal type for he says, "they seem to be formed by the breaking of the waves, the whirl of the water and currents, which have ground stones and rubbish round inside them."

In North America the idea seems to have prevailed at early dates that the potholes were the work of the aborigines, as is indicated by a quotation cited by Manning:[7]

> General Joseph Sewall in his "History of Bath, Me.," says: "Neither history nor tradition informs us how they [the potholes at Bath, Me.] were made, or for what purpose. By some they are supposed to have been used in the performance of some of the religious ceremonies of the nation. An examination of them seems to leave but little doubt that they were made and used by the natives to boil their food in; so limited was their knowledge of the arts and so rude their implements, that they heated water for cooking by throwing stones into it; the pebbles found in and about these holes are such as would resist the action of heat, and, as if by much use, they are all worn and smooth; and the sides of the holes toward the sea being a little lower than the others, by their smoothness show the effect of the action of the pebbles as they were rolled in and taken out of the excavations."

Similar ideas obtain even now in the western states. Turner[8] describes a large group of glacial potholes in granite in the canyon of the North Fork of Mokelumne river, California, about 30 miles southwest of Lake Tahoe. The locality is known as Harris' Salt Springs. The holes, about 250 in number, are from 6 inches to 6 feet apart. The interiors of all the holes are well-rounded and smooth. They extend over an area of about 2,000 square feet. In this locality salt water oozes from crevices in the rocks and collects in several of the lower holes, the water usually being covered with sodium chloride crystals. Indians are said to have congregated here, attracted no doubt by the salt springs. Many small arrowheads are found near by as are also several small mortar holes such as are used by Indians to grind up acorns. The guides and old settlers acquainted with the vicinity accordingly argue that the holes were made by Indians for the purpose of collecting the salt

[7] Manning, P. C., "Glacial Potholes in Maine," *Portland Soc. Nat. Hist. Proc.*, Vol. 2, Part 5, p. 190, 1901.

[8] Turner, H. W., "Glacial Potholes in California," *Am. Jour. of Sci.*, 3d Series, Vol. 44, pp. 453, 454, 1892.

water in order to bring about the concentration of the salt crystals. While the old settlers did not know personally of any such holes being excavated by Indians, it seemed to them that it would not be difficult for Indians to make the holes by building fires on the granite, allowing the rock to cool and repeating the process a number of times, eventually causing the rock to shell off, meanwhile using such tools as they possessed to facilitate the development of the holes.

In view of these early popular misconceptions of their origin, and since similar ideas are still current in some sections; and further because all types of pothole depressions are not to be explained by any one process, it has seemed worth while to attempt a rational classification of these phenomena on the basis of their mode of formation and then to describe briefly each of the types.

Classification of Pothole Depressions

Class A—Allied types of pothole excavations due to the erosive action of water aided by rock fragments and sediment tools, in the general order of their size from largest to smallest.

1. Moulin potholes or giants' kettles.
2. Plunge pools.
3. Normal potholes.
4. Cupholes and Joint wells.

Class B—Types of pothole-like excavations due primarily to solution.

1. Solution potholes.
2. Dent pits.

Class C—Types of pothole-like excavations of rather uncommon occurrence, due to solution, erosion and other processes acting in combination or singly.

1. Tide pools.
2. Potholes due to sea urchins.

Class A, Type 1:

Moulin potholes (also called glacial potholes) are in general to be correlated with what are popularly termed giants' kettles and are associated in origin with the melting of glacial ice. They have perhaps attracted more attention than any of the other types because of their frequent occurrence away from present stream courses. In some cases no other marks of water action are to be noticed in their vicinity. It is particularly interesting to note that in potholes of this type, according to Upham,[9] "generally the edge or lip of the giants' kettles (moulin potholes), whether large or small, is abruptly cut in the rock

[9] Upham, W., "Giants' Kettles Eroded by Moulin Torrents," *Bull. Geol. Soc. of Am.*, Vol. 12, pp. 40–41, 1900.

surface, perhaps sometimes because of their partial removal at the surface by glaciation subsequent to the moulin erosion." "They seldom have a flaringly curved mouth, such as more frequently characterizes potholes seen at the present time in the process of erosion by cascades in brooks and rivers."

Moulin potholes are commonly very large. Upham[10] describes several in the Interstate Park of the Saint Croix Dalles, Wisconsin, among which is one with a diameter of 27 feet, and another that has a diameter of 15 feet and which has a depth of at least 65 feet. A third occurrence in the same locality has a diameter of 12 feet. The depth of this hole according to Upham[11] is stated by Dr. C. P. Berkey to be 160 feet. The moulin potholes of the "Glacier Gardens of Lucerne" in Switzerland are perhaps the best known. Barker[12] has described two potholes of this type located at Crown Point, New York. It should be noted that glacial potholes are of wide distribution; are apparently coextensive with regions of continental glaciation and are also found adjacent to existing glaciers of the Alpine type. Gilbert[13] ascribes these potholes to the work of a moulin or glacial mill which is a stream of water plunging from the top to the base of a glacier through a well of its own maintenance. The water, which is chiefly derived from ice melting, usually has a short course as a stream on the surface of a glacier before reaching the well, and it escapes from the bottom of the well by a channel under the glacier. The moulin originally forms in a crack or crevasse, and in its initial stage the crevasse must extend from the top to the bottom of the ice mass to admit and transmit the water stream. After a time the crevasse generally becomes sealed by regelation except where the falling water maintains an opening. Thus a vertical fall develops and the stream strikes the rock bed beneath with great force. Boulders and sand are carried by the surface stream to the well and at the base of the ice the plunging water picks up rock fragments and sand from the ground moraine and this material is used as tools with which to attack the rock bed. With long enough continuance of such action a hole is formed which deepens and assumes the character of a normal pothole of very large size.

[10] Upham, W., *Ibid.*, pp. 30, 31.

[11] Upham, W., "Giants' Kettles Eroded by Moulin Torrents," *Bull. Geol. Soc. of Am.*, Vol. 12, p. 31, 1900.

[12] Barker, E. E., "Glacial Potholes at Crown Point, N. Y.," *Jour. Geol.*, Vol. XXI., No. 5, July-Aug., 1913, pp. 459-464.

[13] Gilbert, G. K., "Moulin Work under Glaciers," *Bull. Geol. Soc. of Am.*, Vol. 17, pp. 317-320, 1906.

Because it is self evident that a moulin can not maintain itself for an indefinite period in actively moving ice it seems incredible that such large holes in the bed rock could be ground out in the time available. But it is to be noted that moulins develop primarily at the lower ends of very stagnant and inactive glaciers and, further, that the fall of the water may be of very great height. Thus Lubbock[14] relates that the depth of a moulin on the Finster-Aar glacier was found to be 232 meters. This depth would undoubtedly lead to great force in the fall of the water. The mere impact of the water, however, has very little to do with starting the holes, according to Stone.[15] It is chiefly the stones and sediment rolled about that erode. The falling water develops tremendous swirls at the base and these keep the rock tools in active motion. The moulin potholes of regions of continental glaciation are however thought by Upham[16] to have been formed during an early stage of the glaciation, since during that stage the supply of tools would not be too great, as he says would be the case during the latter part of the glacial period.

Class A, Type 2:

Plunge pools are potholes, in general, of large size, occurring at the foot of a vertical or nearly vertical waterfall. At such sites the velocity of the falling water develops especially great energy in swirling stones at the foot of the plunge, and this results in the grinding out of potholes or plunge pools of exceptional diameter (depending on the volume of the water) and depth (depending apparently on the height of the fall). A large plunge pool occurs at the base of the Canadian side of Niagara Falls. According to Spencer,[17] the depth of this pool is 72 feet. In most plunge pools the water is much deeper than it is in the stream channel on their downstream side. Smaller waterfalls develop plunge pools that quite closely resemble normal potholes. In fact there are practically all gradations from plunge pools to the normal type of pothole formed in existing stream channels. It must not be inferred from this, however, that all potholes in existing stream channels are initiated

[14] Lubbock, Sir John, "The Scenery of Switzerland," Macmillan Co., 1898, pp. 92–93, 122.

[15] Stone, G. H., "The Glacial Gravels of Maine and their Associated Deposits," U. S. G. S. Monograph, 34, pp. 324–326, 1899.

[16] Upham, W., "Giants' Kettles Eroded by Moulin Torrents," *Bull. Geol. Soc. of Am.*, Vol. 12, pp. 25–44, 1900.

[17] Spencer, Dr. J. W. W., "Soundings in Niagara Gorge and under the Falls," *Sci. American*, Vol. 99, Aug. 1, 1908, pp. 76–77.

by waterfalls however small. This fact is illustrated in Fig. 2 which shows quite clearly that a pothole may become a plunge pool.

Class A, Type 3:

Normal Potholes.—These potholes occur in the beds of present day streams or recently abandoned stream courses, in places over which the water has flowed either constantly or during its periods of high volume. If still in the process of formation they must be located directly in the course of the water channel at least during occasional periods of flooding. One of the distinguishing characteristics of normal potholes is the presence of waterworn surfaces adjoining the hole. Normal potholes are described in greater detail below.

Class A, Type 4:

Cupholes have been described by Hudson[18] as little potholes that have been cut, not by pebbles, but by sand and silt swirled about by water currents. They rarely exceed 12 centimeters in diameter and may be cut on very steep slopes of a rock surface. According to Hudson,[19] cupholes are somewhat V-shaped, more strictly speaking,—parabolic in vertical sections. (See Figs. 3, 4, and 5.)

The same author also describes *joint wells*[20]—another type of small depressions that occur along joints in rocks that have suffered glaciation. It is his opinion that *joint wells* (see Fig. 6) were cut by combined solution and silt erosion processes and that they are embryonic moulin-potholes in that they are the work of subglacial streams. Hudson, while describing the *cupholes* as "little potholes"[21] caused by wave and undertow acting on the lake shore, is unwilling to have them classed as a form of *incipient* potholes on the ground that they may never become such. He regards their form as being so different from that of

[18] Hudson, G. H., "Some Items Concerning a New and an Old Coast Line of Lake Champlain," N. Y. State Mus. Bull., No. 133, 5th Rept. of the Director, 1908, pp. 160–162, 1909.

[19] Hudson, G. H., "Joint Caves of Valcour Island—Their Age and Origin," N. Y. State Mus Bull., No. 140, 6th Rept. of the Director, 1909, pp. 170–173.

[20] Hudson, G. H., "Rill Channels and Their Cause," Report of the Vermont State Geologist, 1912, pp. 245–246.

[21] Hudson, G. H., "Some Items Concerning a New and an Old Coast Line of Lake Champlain," N. Y. State Mus. Bull., No. 133, 5th Rept. of the Director, 1908, pp. 160–162, 1909.

Photo by G. F. Morgan, Ithaca, N. Y.

FIG. 1. INTERSECTING POTHOLES IN GORGE OF BUTTERMILK CREEK NEAR ITHACA, N. Y. Such a series of potholes indicates the primary importance of pothole erosion processes in the deepening of stream gorges.

Photo by Libbey.

Fig. 2. Series of Plunge Pools and a Waterfall in Lava in Hawaii. Notice how the fully developed pools below the falls have intersected because of enlargement below the water surface thus creating a series of natural bridges. When the pothole at the foot of the falls has developed sufficiently to intersect the base of the similar hollow in the stream bed above, the falls will again retreat and the upper pothole will become a plunge pool. This picture farther illustrates the important part that processes of pothole and plunge pool excavation play in gorge deepening.

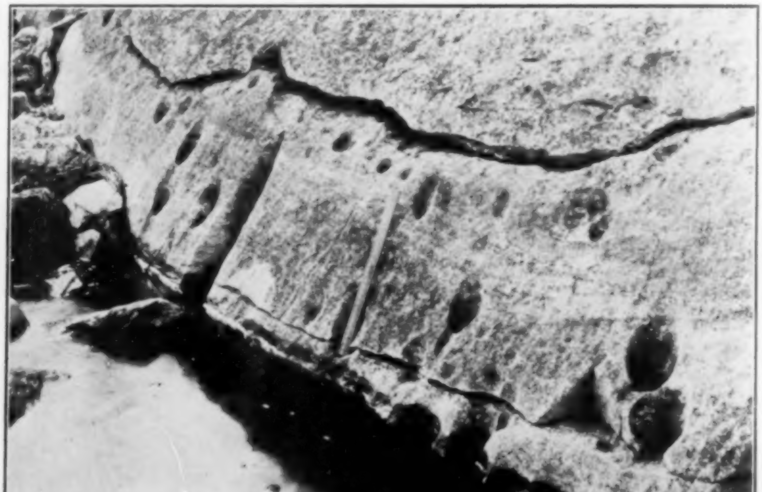


Photo by G. H. Hudson, Plattsburg, N. Y.

Fig. 3. Cupholes cut in Steep Face of Rock on Valcour Island.

typical potholes as to entitle them to a name of their own and in a letter to the writer states that they are made by silt and sand carried by vortex motion and that in his opinion the *cupholes* tell of lake conditions or large bodies of water and not of river conditions.

If his interpretation of them is correct, it is possible that the *cupholes* are in origin akin to the so-called tide pools described in another paragraph and hence may be classed as minute forms of normal potholes. Furthermore, it also seems

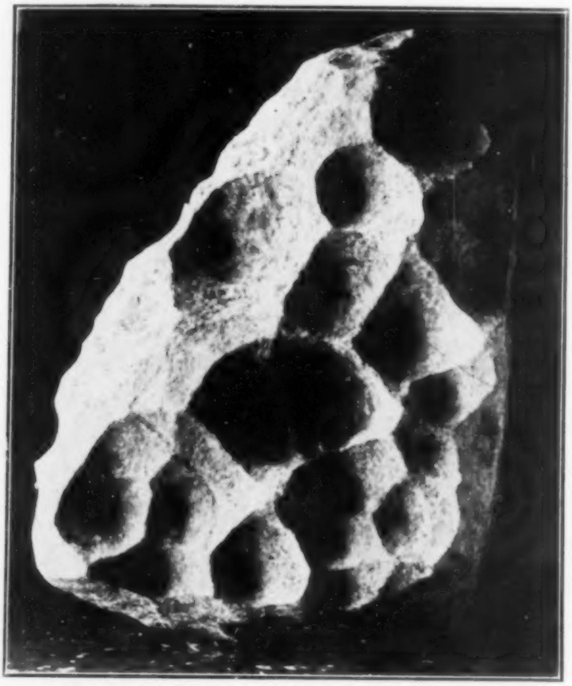


Photo by G. H. Hudson, Plattsburg, N. Y.

FIG. 4. BLOCK OF PURE DOLOMITIC LIMESTONE CUT BY CONFLUENT CUPHOLES. Specimen taken from Valcour Island and is now in the New York State Museum.

probable that the *joint wells* and *dentpits* (a third type of similar small depression) are all very small forms of moulin potholes or solution potholes. Thus the *cupholes* are due primarily to erosive action of fine sediment whirled by the water; the *dentpits* to solution action; while the *joint wells* may be due to both solution and grinding.

Class B, Type 1:

Solution Potholes.—This type includes all the holes that are

formed primarily by solution action. Such holes are most numerous in soluble rocks, notably limestone. They may almost invariably be distinguished from other potholes by the rough solution surfaces of their interiors.

Class B, Type 2:

Dentpits as described by Hudson[22] have been previously mentioned as vortex formed, shallow concavities on rather pure calcareous rock where the water carries but little matter in mechanical suspension. They are due mainly to solution and their width greatly exceeds their depth. The diameters of

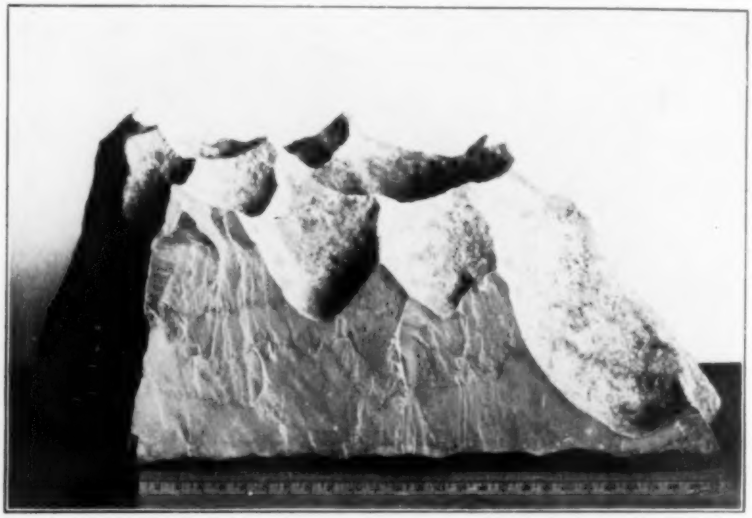


Photo by G. H. Hudson, Plattsburg, N. Y.

FIG. 5. VIEW OF FRACTURED END OF THE LOWER PORTION OF THE BLOCK SHOWN IN FIG. 4. Presents a side view of the cupholes and illustrates parabolic vertical sections of the same. Shows also the edge of the dent-pitted surface below and indicates approximately the quantitative value of the two forms of erosion as geological agents.

dentpits are usually between 1 and 5 centimeters. In vertical sections they present rather circular outlines. No silt is ever found in these depressions which are well shown in Fig. 7.

Class C, Type 1:

Tide pools are a rather uncommon type of pothole depression occurring along rocky coast lines. Their formation seems

[22] Hudson, G. H., "Joint Caves of Valcour Island—Their Age and Origin," N. Y. State Mus. Bull., No. 140, 6th Rept. of the Director, 1909, pp. 165–173, 1910.

to be due to a variety of processes. A particular occurrence of such holes along the west coast of Vancouver Island, near Port Renfrew, B. C., is described and explained by Henkel.[23] The principal rock formations at this locality are, in their order from the surface downward, sandstone, conglomerate and shale. In many places the sandstone has been worn away leaving the conglomerate or the shale as the surface rock. Depressions of varying shape and depth are found in all three kinds of rock but are best developed in the sandstone because of the "extreme softness" of this rock. The pools are also numerous in the shale, but only few occur in the conglomerate. In the sandstone the pools generally occur in strata that are nearly horizontal and they are especially numerous in a gently dipping

Photo by G. H. Hudson, Plattsburg, N. Y.

FIG. 6. JOINT WELLS IN LIMESTONE LEDGE ON VALCOUR ISLAND.

sandstone which contains many concretions. This formation is locally known as the "devil's billiard table." Apparently

[23] Henkel, Isabel, "A Study of Tide Pools on the West Coast of Vancouver Island," *Postelsia*—The Year Book of the Minnesota Seaside Station, 1906, pp. 277, 304.

the concretions have been worn out in many places leaving a depression. The number, size and irregularity of the pools increases with the slope.

The majority of the smaller pools are circular but the larger ones are generally elliptical and give evidence of having been formed by the union of two or more smaller pools. From depressions a few inches in diameter, the size varies to those 30 feet long, 20 feet wide and 10 to 15 feet deep. Plant and animal life is commonly found in many of the pools, notably sea urchins, mussels and barnacles, and in some pools boulders occur that are apparently of the same composition as the concretions. The larger pools, however, contain the fewer boulders.

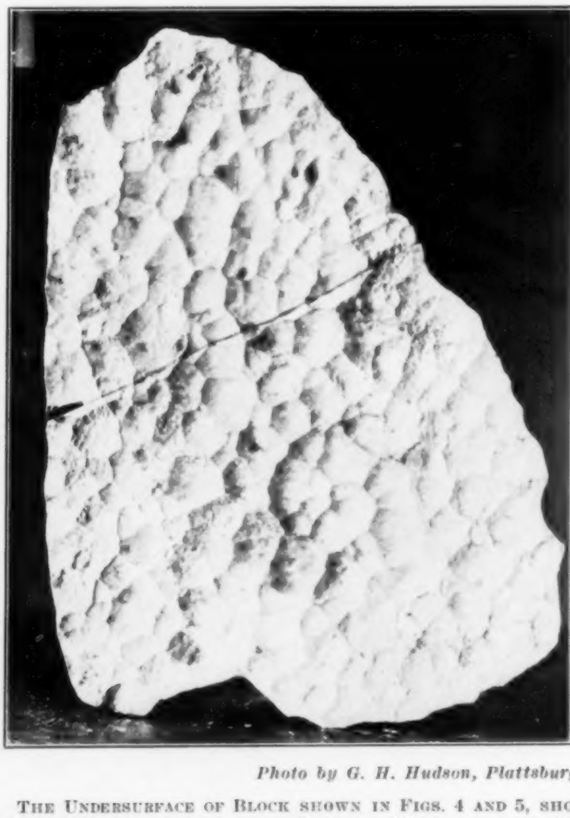


Photo by G. H. Hudson, Plattsburg, N. Y.

FIG. 7. THE UNDERSURFACE OF BLOCK SHOWN IN FIGS. 4 AND 5, SHOWING DENT-PITS. Figure should be viewed at an angle that will eliminate the impression of botryoidal surface.

Henkel considers the occurrence of the concretions to be the most potent factor in the development of sandstone pools. After becoming detached from the formation the concretions

are hurled about inside the depressions gradually enlarging them while at the same time the concretions are reduced in size. This process of enlargement may be aided by plant and animal life exerting a disrupting influence upon the rock. Tide pools in general, however, according to this author are initiated by a variety of conditions and processes, among which may be included: cracks in the rock; concretions; lines of stratification; erosion by waves, tides and wind; action of carbon dioxide; variation in temperature, both of water and of the air; and the action of plants and animals.

Class C, Type 2:

Potholes due to sea urchins are depressions occurring along rocky coast lines and are a type very closely resembling Tide Pools. Such potholes are described by Fewkes[24] who states that they are comparatively rare. Some were found near Grand Manan, New Brunswick, and also at Biarritz, France. They are apparently most commonly found on coasts beaten by a strong sea and in places where there is considerable tidal variation. It seems that the cavities owe their origin primarily to sea urchins, the teeth and spines of which gradually hollow out the depression. Water action rolling these spiny creatures about, and pebbles also apparently facilitates the development of such pools.

(To be concluded)

[24] Fewkes, J. W., "On Excavations made in Rocks by Sea Urchins," *The American Naturalist*, Vol. 24, pp. 1–21, January, 1890.

Charles Emile Picard

recently elected permanent secretary of the Paris Academy of Sciences in succession to the late Jean Gaston Darboux. Both M. Picard and M. Darboux have been professors of mathematics and have been active in matters of national defense and in increasing the services to the nation of the Paris Academy of Science. Like M. Painleve the present premier of France, also professor of mathematics, their activities seem to disprove the prevalent idea that mathematicians are not efficient in practical affairs.

THE PROGRESS OF SCIENCE

WORK OF THE CORPS OF ENGINEERS OF THE ARMY

THE Corps of Engineers of the Army since April 6 has not only been supplying the engineer equipment for an army of a million men, but has undertaken the unprecedented task of furnishing railroads complete from the United States for operation in France. The engineers construct the free arteries through which flow great armies, reinforcements, supplies and ammunition to the extremities of the lines.

From March 1 to November 1 the Corps of Engineers increased its personnel from 256 officers on the active list to 394 officers and 14 retired officers on active duty and in addition has commissioned more than 5,000 reserve officers. The enlisted force has expanded from 2,100 to 95,000, and there has also been a heavy increase in civilian employees. In addition, nine railroad regiments and one forestry regiment have been raised as part of the National Army, Seventeen pioneer regiments have been authorized as part of the National Army and are rapidly organizing. National Guard units, equivalent to about seven regiments, have been called into the Federal service, and their reorganization into 17 pioneer engineer regiments for the 17 divisions of National Guard troops is well under way.

Engineer officers' training camps were established in each of the 16 training camp areas the number of candidates for engineer commissions taken from each camp being 150. After a month's training in the same camps with candidates for commissions in other branches of the service the engineer sections were transferred to three engineer training camps with special facilities for technical instruction, one in the vicinity of Washington, one at Fort Leavenworth, Kans., and one at Vancouver Barracks, Wash. Instruction was continued there for two months. In August, 1,900 candidates were graduated and are now holding commissions.

Large numbers of engineer graduates of training camps have been assigned to new regiments and special units are being organized and the training of enlisted men in the National Army will be largely under their supervision. A number are in France for special training. On December 1 about 1,200 Engineer Reserve officers will be graduated from a second engineer officers' training camp.

A duty imposed upon the enginers has been the purchase of the necessary engineer equipment for more than 1,000,000 men. The urgent deficiencies act approved June 15, 1917, appropriated for the purpose amounts aggregating in excess of $130,000,000, an amount comparable with the purchase of material equipment, and supplies for the Panama Canal during the ten years of its construction. The urgent deficiencies act approved October 6, 1917, provides $198,100,000 additional for engineer purposes and it is expected that all of this will be expended during the present fiscal year.

Within 350 hours after the Engineer Corps, following the declaration of war, advertised for equipment, awards had been made covering the requirements of 1,000,000 men, a total of 8,700,000 articles, which included among other items 4 miles of pontoon bridge. Approximately two months was the average time of delivery secured on all

of this material. On September 7, two weeks after receipt of instructions, equipment was en route to the various National Guard and National Army organizations at cantonments throughout the country. These shipments comprised a total of about 48,000,000 pounds in some 64,000 separate cases and packages.

By November 1 the outstanding obligations on orders placed for engineer material, equipment, and supplies, aggregated $130,000,000, and disbursements in payments for material delivered had reached the sum of $15,000,000 per month. Another important task of the engineers has been to provide efficient methods for the receipt, storage, and shipment abroad, with proper accounting system, for this mass of supplies as well as for the vast equipment for field operations and construction work.

The engineers of the railway section have undertaken to transport and install and put into operation overseas a complete railroad equipment. The railway problem in the theater of operations in France involves not only the organization, equipment and military training of railroad troops for the construction, maintenance and operation of standard and narrow gauge roads necessary for the supply of our armies, but also the purchase, inspection and shipment of immense quantities of railroad equipment—rails, ties, locomotives, cars, shop tools, etc.—necessary for the development of adequate port facilities, construction of new lines and their successful operation. The estimate of the situation in France was confirmed by the French commission, headed by Marshal Joffre, and the means of meeting it have been carried on with intensity.

Trained officials in various departments of American railroads were called upon for the officers, and experienced railroad employees for the enlisted men, of the nine railroad regiments, each of 33 officers and approximately 1,100 men.

The cost of materials ordered to date is approximately $70,000,000 including some hundreds of locomotives, more than 100,000 tons of steel rails, more than 3,000 complete turnouts, 500,000 ties, 12,000 freight cars, 600 fill and ballast cars, 600 miles of telephone wire and apparatus, as well as vast quantities of construction and repair equipment.

The engineers have also undertaken the work of organizing and equipping special troops for special services, such as lumber supply, road construction, sanitary construction, camouflage service, gas and flame service, mining work, mapping, etc. Preferred attention has been given to the organization and equipment of the first forestry regiment, to be sent to France to produce lumber and timber from French forests. Three additional regiments are to be organized. The cooperation of the Forestry Service of the Department of Agriculture has been extended in the selection of personnel and equipment. In addition to all of these duties, the Engineer Corps has maintained its regular service in the preservation and improvement of navigable waters in the United States and construction of coast defenses. New batteries are being pushed to completion with energy.

THE NATIONAL ASSOCIATION OF AUDUBON SOCIETIES.

THE European war has so stimulated a study of the economic uses of birds that the National Association of Audubon Societies was able to report at its annual meeting on October 30 that its sustaining membership had increased thirty-three and a third per cent. during the last year. The growth of the society and the generous financial support

which it has received encouraged its secretary, Mr. T. Gilbert Pearson, to suggest a campaign for the raising of funds with which to build a permanent headquarters for the association in New York City.

The National Association of Audubon Societies, with which are affiliated 134 organizations throughout the U. S., has been devoting special attention to the protection of birds which help conserve crops by destroying weed seeds, rodent pests and injurious insects. This, in no small measure, is regarded as the reason for the movement being joined by so many prominent and influential persons who have been impressed by this service in behalf of the American people. During the year the association enrolled one patron and one hundred and eleven life members. The sustaining membership increased from 3,024 to 4,030.

A significant indication of the activity of the association in conservation the last year is given by the reports of the wardens. In the twelve months just closed forty-six wardens were employed and patrol boats were provided for three additional government wardens. During the year the association put in commission a new warden patrol boat on Klamath Lake, Oregon, while another such craft to be paid for by the income of the Mary Dutcher Memorial Fund is being built for work on the Pelican Island Reservation, Florida. An important feature of the work is the guarding of colonies of aquatic fowl. Reports of the wardens of rookeries show that in the aggregate something over 1,043,000 water-birds were bred in the various protected sanctuaries. This estimate covers forty species including gulls, skimmers, terns, egrets, herons, ibises, pelicans, and a few quillemots, eider ducks, Florida ducks, limpkins, and puffins. Innumerable small birds and various migratory shore-birds also found protection in these guarded areas.

Coordination of the work of the national association and the state and local endeavors is bringing splendid results in bird protection. Some places recently set aside for the welcoming of the feathered hosts are the Julia Hanson Bird Reservation at Fort Meyers, in Florida, while the entire community at Winter Park in that State has been made an avine haven. Indiana reports that a sanctuary has been established near Muncie and also that a new State Park has been created and designated McCormick's Creek Canyon Bird Reservation. The Beaver Field and Audubon Club has recently established a twenty-five acre sanctuary at Beaver, Pennsylvania.

An important new development of the work of the association is the Saturday morning bird-walk which starts at eight o'clock from the Music Stand at the head of the Mall, Central Park, New York City, weather permitting. The leader of this weekly expedition in birdland is Mr. Walt F. McMahon, of the headquarters' staff. The object of the Saturday walks is to demonstrate to the teeming millions of the metropolis that in the very center of a realm of towering buildings there is a wild life as interesting as that of the distant thickets and forests. The lecturer in his addresses in which he reviews the observations of an hour is able to impress many lessons concerning the economic uses of birds. This work will undoubtedly extend to other cities.

The association has formed in the last year in the United States and Canada 11,935 Junior Audubon Clubs, with a total membership of 261,654 paid members, among the school children of the nation, an increase of 50,000 over 1916. This work, as heretofore, was financed to the extent of $5,000 by Mrs. Russell

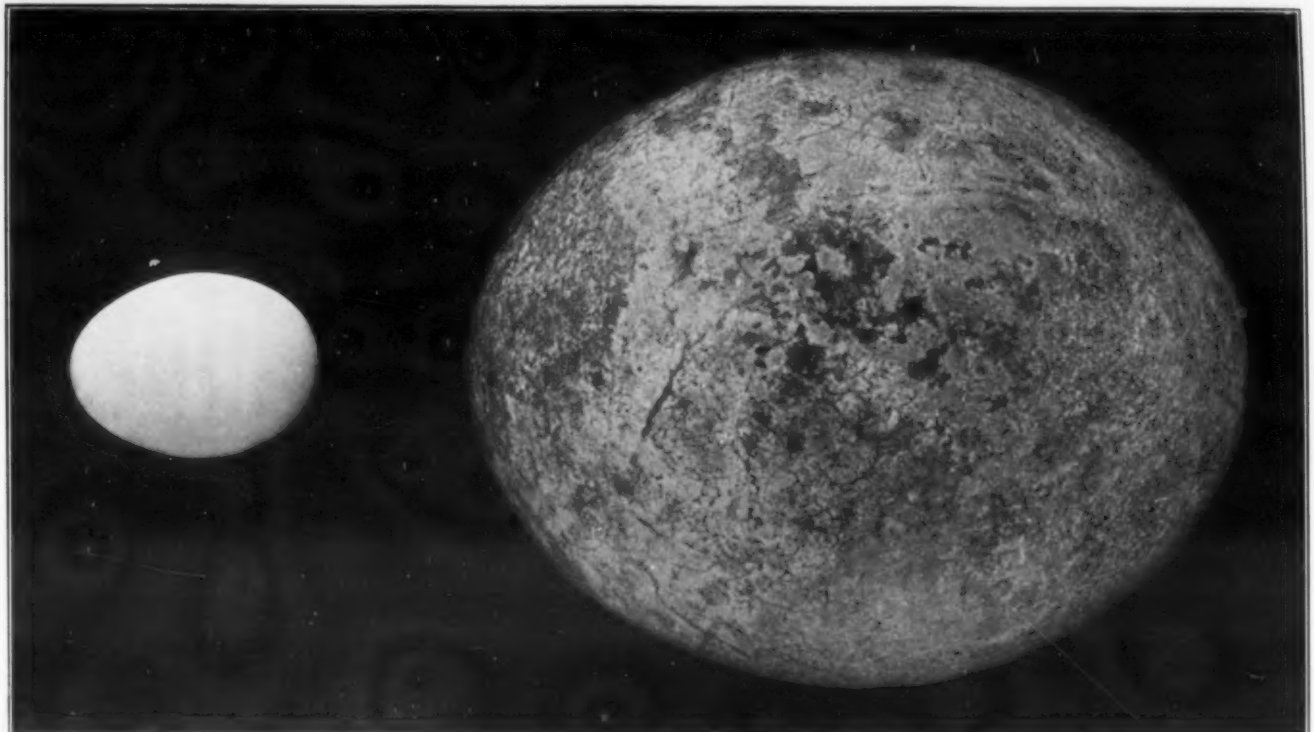
Sage and by $20,000 from a benefactor of the birds whose identity as far as is known has never been discovered by anyone, save the gentleman who annually sends the checks. After five years during which $94,000 have been received from this source, the only knowledge that the secretary has regarding the donor is that the money probably comes from a man. The educational work of the National Association has been extended in many other directions through field agents, lecturers, summer schools, exhibitions and by the distribution of large quantities of literature. In every branch there has been manifested a growing interest in this important enterprise which has done so much for the protection of the birds and animals of field and forest.

THE CAUSES OF DEATH BY OCCUPATION

BASED upon 94,269 deaths of male and 102,467 deaths of female industrial policyholders, 15 years of age and over, as recorded in 1911, 1912 and 1913, by the Metropolitan Life Insurance Company, tuberculosis caused the death of 20.5 per cent. of the former and 14.4 per cent. of the latter, while organic diseases of the heart were responsible for 12 per cent. of the deaths of males and 14.8 per cent. of the deaths of females. The average age of men dying from tuberculosis was 37.1 years and of women 34.1 years. Of males the lowest average age at death, 31.1 years, was among those who died from typhoid fever, and of females the lowest average age at death, 29 years, was among those who died at child birth. By occupation, the lowest average age at death was 36.5 years among bookkeepers and office assistants and the highest average age was 58.5 years among farmers and farm laborers. These facts are brought out in tabular form in a bulletin entitled "Causes of death by occupation," a study made by Louis I. Dublin and recently issued by the Bureau of Labor Statistics of the U. S. Department of Labor.

Tuberculosis was responsible for the largest number of deaths among clerks, bookkeepers and office assistants (35 per cent.); compositors and printers (34.1 per cent.); gas fitters and steam fitters (31.6 per cent.); longshoremen and stevedores (29.2 per cent.); teamsters, drivers and chauffeurs (28.2 per cent.); saloonkeepers and bartenders (26 per cent.); machinists (25 per cent.); cigar makers and tobacco workers (24.1 per cent.); textile mill workers (22 per cent.); iron molders (21.9 per cent.); painters, paperhangers and varnishers (21.9 per cent.); masons and bricklayers (19 per cent.); bakers (18.8 per cent.); laborers (16.4 per cent.); blacksmiths (14 per cent.). Accidental violence was responsible for the largest number of deaths among railway enginemen and trainmen (42.3 per cent.); railway track and yard workers (20.8 per cent.); and coal miners (20.4 per cent.); while the largest number of farmers and farm laborers (16.4 per cent.) died from organic diseases of the heart, due to the facts that the prevalence of these diseases increases with age and that the average age at death of those in this group is higher than any other group.

Similarly, among women the largest number of housewives and housekeepers (15.2 per cent.) died from organic diseases of the heart for the same reasons stated above, while tuberculosis took the largest proportion of clerks, bookkeepers and office assistants (42.4 per cent.); clerks and saleswomen (38.7 per cent.); textile mill workers (35.5 per cent.); dressmakers and garment workers (27.8 per cent.); and domestic servants (15.9 per cent.). The average age at death was 26.1 years among clerks, book-



EGG OF A PREHISTORIC OSTRICH COMPARED WITH AN EGG OF THE COMMON HEN

This specimen of the egg of the prehistoric ostrich (*Struthio-lithus Chersonensis*) has recently been acquired by the American Museum of Natural History, New York City. It is equal in volume to forty hen's eggs and is more than twice the size of the egg of the modern ostrich. There are two other fossil eggs of this description in existence, but they are broken; this specimen is perfect. The bones of this species have not been found, so it is known only from the eggs.

keepers and office assistants, and 53.3 years among housewives and housekeepers.

The statistics given in the bulletin indicate that respiratory diseases are prominent where the industrial worker is exposed to colds, drafts and dampness (as among masons and bricklayers) or to violent changes of temperature (as among teamsters, drivers and chauffeurs). Organic diseases of the heart have a high proportional frequency in cases where the work is heavy and the cardiac powers are overtaxed (*e. g.*, among iron molders). Suicide is frequent where depressing influences are present (as among bakers and cigar makers). Typhoid fever is high where questionable water supplies are used (as among enginemen and trainmen, farmers, iron molders and laborers).

SCIENTIFIC ITEMS

WE record with regret the death of Dr. R. H. Ward, known for his work in microscopy and from 1869 to 1892 professor of botany in the Rensselaer Polytechnic Institute; of Sir William James Herschel, discoverer and developer of the system of identification by fingerprints; of William Robert Sykes, the inventor of the lock-and-block system of railway signalling, and of A. J. F. Dastre, director of the laboratory of animal physiology at the Sorbonne, the University of Paris.

A MEMORIAL meeting for Professor Wm. Bullock Clark was held at the Johns Hopkins University on the Sunday afternoon of November 4, President Frank J. Goodnow presided. The speakers were Dr. Charles D. Walcott, the secretary of the Smithsonian Institution; Mr. R. Brent Keyser, the president of the board of trustees of the university; Professors Harry Fielding Reid and J. S. Ames, of the faculty, and Judge J. T. C. Williams, of the Baltimore Juvenile Court.—A memorial tablet has been unveiled at Oxford, commemorating the life and work of Roger Bacon. The tablet has been fixed to the old wall of the city, dating from early in the thirteenth century, close to the site of the Grey Friars Church in the precincts of which Roger Bacon was buried. The church has long since disappeared, but the position of the burial ground, though not the exact spot of Bacon's grave, is known. After the celebration at Oxford in 1914 of the seven hundredth anniversary of Bacon's birth, it was thought fitting that in addition to the statue then created in the University museum, a permanent and public memorial should be set up as near as possible to the site of the Franciscan friary in which Bacon passed so many years of his strenuous life.

PLANS are well advanced for the Pittsburgh meeting of the American Association for the Advancement of Science from December 28 to January 2. The Carnegie Institute, the Carnegie Institute of Technology and the University of Pittsburgh are uniting in preparing to entertain the association. Dr. W. J. Holland, director of the Carnegie Museum, is chairman of the committee on arrangements, and S. B. Linhart, secretary of the University of Pittsburgh, is secretary of the committee. Secretaries of affiliated societies and of other organizations meeting at this time are requested to send to the secretary as soon as possible the approximate number of members of each organization who expect to attend; and the time for which meetings are to be arranged.

DEAN R. BRIMHALL, of Columbia University, has accepted the position of managing editor of THE SCIENTIFIC MONTHLY.

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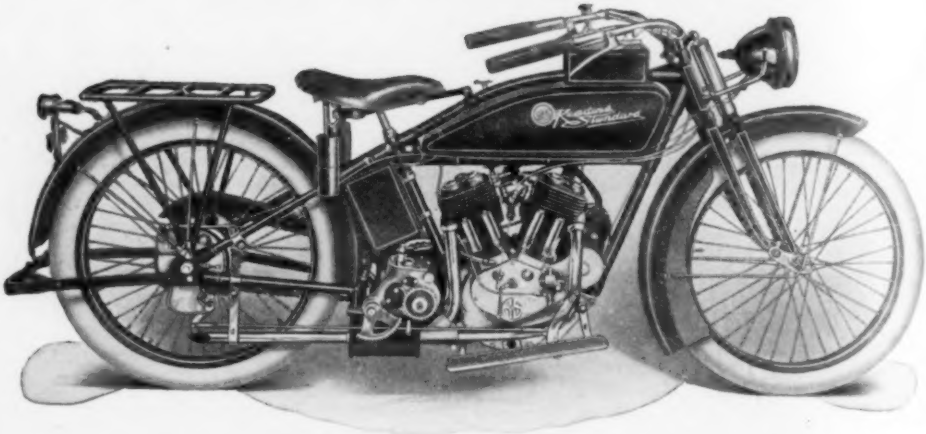

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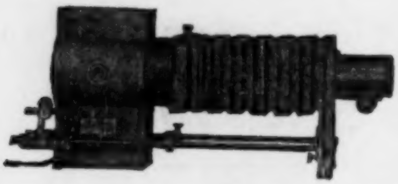

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